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Report No. 95.

THE AGRICULTURAL POSSIBILITIES OF
THE CANAL ZONE.

PART I. RECONNOISSANCE SOIL SURVEY.

BY

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Scientist in the Soil Survey.

PART II. THE OUTLOOK FOR AGRICULTURE.

BY

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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
BUREAU OF SOILS,

Washington, D. C., October 11, 1911.

SIR: In the summer of 1909 the department received a note from the President transmitting a letter from the honorable the Secretary of War, inclosing a communication from Col. George W. Goethals, chairman and chief engineer Isthmian Canal Commission, requesting the appointment of a committee composed of employees of the Department of Agriculture to investigate and report upon the possibilities of agriculture in the Canal Zone. In November, 1909, Mr. W. A. Taylor, then pomologist in charge of field investigations of the Bureau of Plant Industry, and Mr. Hugh H. Bennett, expert in the soil survey, of the Bureau of Soils, proceeded at your direction to the Isthmus for the purpose of studying the climate, soil, crops, and other conditions bearing upon the development of agriculture in the region bordering the canal. A month or more was spent in making a reconnoissance soil survey and in gathering other material for a report.

The results of these investigations are embodied in the accompanying manuscript and map, which we have the honor to recommend be published as a report of your office.

Very respectfully,

B. T. GALLOWAY,
Chief Bureau of Plant Industry.
MILTON WHITNEY,
Chief Bureau of Soils.

HON. JAMES WILSON,
Secretary of Agriculture.

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THE AGRICULTURAL POSSIBILITIES OF THE CANAL ZONE.

PART I. RECONNOISSANCE SOIL SURVEY.

By HUGH H. BENNETT, *Scientist in the Soil Survey.*

INTRODUCTION.

The maintenance in the Canal Zone of a large construction force dependent almost wholly upon outside sources for food has created a strong demand for fresh or locally produced vegetables, fruits, meats, and dairy products, a fact which, coupled with increasing interest in this portion of the Tropics, has led to an investigation of the agricultural conditions and possibilities of the Canal Zone lands. In order to ascertain the opportunities for development and utilization

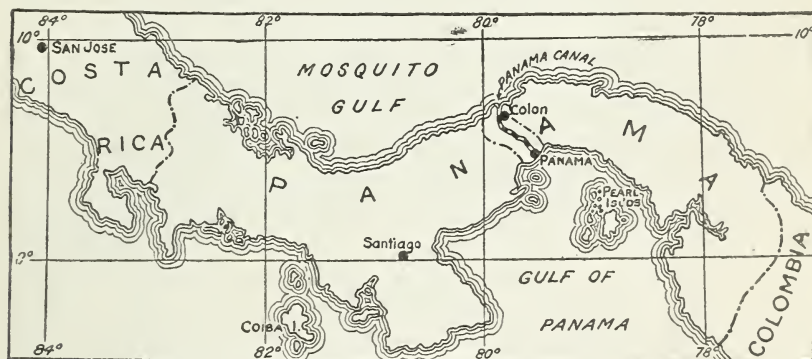


FIG. 1.—Sketch showing location of the Panama Canal.

of this extensive area of land, largely unused except for a most primitive patch agriculture, a reconnoissance survey was made of the zone in November and December, 1909. The results of this survey are submitted below.

DESCRIPTION OF THE AREA.

The Canal Zone comprises a strip of land 10 miles wide (extending 5 miles on each side of the center line of the canal) and approximately 45 miles long, crossing the Isthmus of Panama in a southeasterly direction from the Caribbean Sea on the Atlantic side to the Bay of Panama on the Pacific, with an area of about 450 square

miles. The impounding of the waters of the Chagres River by the erection of the dam at Gatun will create a fresh-water lake at an elevation of 85 feet above sea level, with an area of about 164 square miles, of which about 94 square miles will be within the Canal Zone. A smaller lake about 55 feet above sea level and 2 square miles in area will be created by the dam at Miraflores, on the Pacific side of the Isthmus. There will therefore be left in the Canal Zone an uninundated area of about 350 square miles. As this includes the land occupied by cities and villages, the right of way of the Panama Railway, reservoir watersheds, canal dumps, etc., the maximum area available for consideration for all agricultural uses probably will not exceed 325 square miles.

The surface configuration of that portion not to be inundated is in the main extremely hilly, a fact having considerable bearing upon cultural possibilities. From an agricultural standpoint there are four main topographic divisions, namely: (1) The low, flat coast fringes and the alluvial stream bottoms lying outside of and principally below the level of Gatun Lake; (2) the narrow strips of flat to undulating stream bottoms lying largely above the level of the impounded waters of Gatun Lake; (3) the gentle lower slopes, imperfectly developed lateral ridges, and low hills; and (4) the steep, high hills.

The country on the Atlantic side of Gatun Lake is characterized by its numerous, very irregularly distributed, low, conical hills ranging in elevation from about 50 to 100 feet. The "Monkey Hills" near Mount Hope are peculiarly flat topped and uniformly about 50 feet in height. The higher hills to the west and south have more nearly rounded peaks, many of which are laterally grooved by slight drainage depressions. But the contours on the whole are remarkably smooth, there being very few abrupt breaks, such as cliffs and deep gorges, a feature that holds good throughout the entire zone. Drainage is through winding, narrow, smooth-sloped valleys, which often seem more like depressions than true valleys. Topographically this section is fairly well suited to cultivation.

In the Chagres River Valley there are a number of low, isolated hills which will stand above the level of Gatun Lake as islands. Some of these embrace several hundred acres of good clay land, the topography of which is fairly favorable to cultivation with the plow.

Beginning with the uplands to the south of the main body of Gatun Lake, or, roughly, to the south of a line crossing the zone at right angles, a little north of Bohio, the region is characterized by numerous rounded hills unsymmetrically and irregularly distributed over the entire area southward to the Pacific Ocean. They range in elevation from a few hundred feet on the north to nearly 1,000

feet at the line of the Continental Divide near Culebra. Northward from Gorgona the hills become noticeably lower and the proportion of land of easy slope suited to cultivation is greater than to the south.

It would be difficult to imagine a region more hilly than the southern portion of the Canal Zone. The entire country is so broken by one hill after another that well-defined continuous ridges are almost entirely lacking. There are, however, roughly developed drainage divides which, viewed in places from the main valley slope, sometimes appear as unbroken ridges flanked by rounded lateral hills, as is well illustrated in the valley to the west of Empire. But closer view of these divides reveals a most uneven surface configuration. The valleys between the numerous hills here are extremely variable in depth, so that there are many minor high valleys lying above the deeper major stream depressions through the divide regions. This entire southern region is ramified by an intricate drainage system which favors the rapid run-off of rain water. Along their lower courses, where the fall is less, the streams are usually bordered with narrow fringes of flat bottom land. Many of the smaller tributaries descending rapidly to the larger streams are merely wet-weather drainage-ways of short length and without alluvial bottoms.

Owing to the steepness of the upper slopes of the hills, only the lower-lying lands can be plowed for cultivation. There are numerous areas of low hills and gently undulating slopes favorable for agriculture, but fully 75 per cent of the country south of Gorgona is too steep for cultivation, except with hand tools. Most of this land can be used for fruit and hand-cultivated crops. The greater part of the land between Miraflores and Balboa must first be reclaimed by artificial drainage.

CLIMATE.

The climate of the Canal Zone is humid and typically tropical. With a very narrow annual range in temperature, but with marked contrasts in quantity of rainfall, the seasons are aptly divided into dry and rainy. The precipitation means for the dry-season months of January, February, and March are 0.79, 1.15, and 3.33 inches, respectively, at Ancon (Pacific coast), Gamboa (central division), and Cristobal (Atlantic slope), as against the wet-season (April to December, inclusive) means of 7.57, 8.71, and 13.46 at the same stations. The dry season proper begins usually about the middle of December, although there are occasionally considerable variations from this. Fairly heavy precipitation sometimes occurs in the dry season, particularly on the Atlantic slope. Normally the season is characterized by cloudless skies, constant winds, and such scanty rainfall that many crops which make steady growth throughout the

rainy months now hasten to maturity, practically cease to grow, or are completely parched unless irrigated. The prevailing type of corn planted about December 1 usually matures the latter part of February; cassava, although growing steadily throughout the wet season, makes but slight headway in the dry; while "Para" and a number of other native grasses are withered completely. Northern vegetables are unable to survive the dry season, but certain tropical species, such as the chayote (*Sechium edule*), and many tropical fruits are uninjured or only slightly retarded in growth. Many trees shed their leaves at this time of the year, which corresponds to winter or the dormant season of plants in temperate zones.

April, while normally a dry month as compared with the other rainy months, is usually too humid to be included with the dry season. The rainy period proper is characterized by frequent heavy showers, torrential downpours that may continue for many hours, with occasional protracted drizzling rains and heavy fogs. The heaviest rains usually occur in November, the maximum recorded for this month (at the time of this survey) being 43.01 inches at Cristobal. The maximum precipitation during the period 1905-1909 for one hour was 5.87 inches in June, 1906, at Balboa (La Boca); for one day in December, 1906, 10.48 inches at Gatun: The prevailing direction of the moisture-laden winds of the wet season is from the northwest, causing heaviest precipitation along the shores of the Caribbean Sea. Forenoon precipitation averages less than that for the other divisions of the day, the maximum rainfall coming in the afternoon between the hours of 1 and 3, which fact, coupled with the usual rapid dissipation of fogs, accounts for the prevailing clearer weather of the mornings. One, however, soon learns to go prepared for showers or downpours during the wet months.

The growth of vegetation during the rainy season is phenomenal. An abandoned or untended clearing is quickly covered with a dense tangle of the ubiquitous wild plantain and other rapidly growing plants, while unseasoned fence posts cut from soft-wood trees, such as the "hog plum" (*Spondias* sp.), driven into, or in many cases even laid upon, the ground take root and soon produce trees. Many northern flowers and vegetables are forced by the warm, humid climate into wood and leaf growth at the expense of blossoms and fruit. Cowpeas and cucumbers fruit fairly well throughout the rainy season, as do also a number of other vegetables. Most of the indigenous plants make rapid development until checked by the scant supply of moisture attendant on the rapid drying out of soils in the dry season. Owing to the great surface inequality of the country and the imperviousness of the clayey soils, run-off is extremely rapid. With a few days of sunshine exposed soils dry out sufficiently to cause



FIG. 1.—CANAL ZONE FARM HOME.

[The machete in the hand of the man at the left and the pointed stick beside him are the only implements used in clearing land, planting, and caring for crops.]



FIG. 2.—A CORN PATCH ON A HILLSIDE NEAR PEDRO MIGUEL, CANAL ZONE.

[The trellises near the hut support a rank growth of chayote (*Chayote edulis*).]



FIG. 1.—TYPICAL WEST INDIAN SHACK GARDEN AND PROPRIETOR NEAR PEDRO MIGUEL.



FIG. 2.—CHINESE GARDEN NEAR EMPIRE, CANAL ZONE.

excessive baking and cracking. When land is to be broken to any considerable depth by plowing, advantage should be taken of the first favorable weather during the latter part of the wet season, due care being taken in all cases that the soil is in proper condition with respect to moisture; that is, not too soggy or sticky.

Lying in the Torrid Zone, between the parallels of $8^{\circ} 53'$ and $9^{\circ} 25'$ of north latitude, and with a mean elevation much less than 1,000 feet, the temperature of the Canal Zone is necessarily high throughout the year. The thermal equator or line connecting points of maximum annual temperature passes very near but a little to the south of the Isthmus of Panama.¹

The mean annual temperature is about 80° F., that of the Pacific slope being slightly higher than the mean for the Atlantic slope. Monthly means are remarkably uniform. The average daily range of temperature is from 72° F. to 86° F., with little variation between "summer" and "winter," the wet and dry seasons. The extreme range is approximately included within the limits of 68° F. and 97° F. It is generally quite pleasant in the shade, while the nights are nearly always cool. The direct rays of the sun are very oppressive, especially in the rainy season, when the air is often damp and muggy, although sunstrokes are rare. Strenuous exertion rapidly exhausts and should be guarded against, particularly by the unacclimated. During the rainy season the humidity is excessive, especially in the forenoon, when it goes as high as 90 per cent. Lower humidity prevails during the afternoons.

The following tables include meteorological data recorded along the line of the Panama Canal:

Meteorological data for Canal Zone, 1906.²

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Maximum temperature, degrees.....	95	97	92	94	93	89	92	91	92	92	96	90	91.5
Minimum temperature, degrees.....	71	69	69	71	72	70	71	71	73	71	70	70	70.6
Mean temperature, degrees.....	81	81.4	1.6	2.2	81.8	79.9	79.8	80.2	81.4	80	79.8	79.1	80.7
Relative humidity, per cent.....	90	90	88	86	89	90	92	91	90	87	91	87	89.3
Sunshine, per cent of possible.....	61	67	61	47	49	42	38	41	38	51	32	54	43

¹ The observations made at the Isthmus show that it is not the extreme temperatures that are to be feared. These temperatures are more favorable * * * than some experienced from time to time in the United States, even at the north. The complete absence of frost and the great uniformity of climate afford valuable advantages. In tropical regions it is not the excessively high temperatures which increase the difficulties of out-door labor and construction, but those which remain permanently high and are accompanied by great humidity of the air and heavy rainfall.—Climatology of the Isthmus of Panama, by Abbott.

² From Canal Zone Pilot.

Monthly and annual normals of precipitation for Pacific, Central, and Atlantic divisions of Canal Zone.¹

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Pacific slope, Ancon (average 11 years).....	<i>In.</i> 0.93	<i>In.</i> 0.58	<i>In.</i> 0.87	<i>In.</i> 2.30	<i>In.</i> 8.50	<i>In.</i> 8.57	<i>In.</i> 8.02	<i>In.</i> 7.34	<i>In.</i> 8.02	<i>In.</i> 10.70	<i>In.</i> 11.15	<i>In.</i> 3.21	<i>In.</i> 70.19
Central division, Gamboa (average 27 years).....	1.98	.67	.80	3.54	10.72	9.64	10.14	12.46	10.65	12.60	11.76	6.89	91.85
Atlantic slope, Cristobal (average 38 years).....	3.99	1.39	1.60	4.23	12.45	13.11	16.48	15.22	12.48	13.98	21.26	11.93	128.12

¹ 1909 Report Isthmian Canal Commission.

Annual maximum and minimum precipitation for Pacific, Central, and Atlantic divisions of Canal Zone.²

	Maximum.	Minimum.
	<i>Inches.</i>	<i>Inches.</i>
Pacific slope, City of Panama (4 years).....	84.73	45.59
Central division, Gamboa (15 years).....	136.58	71.65
Atlantic slope, Colon (15 years).....	154.89	86.54

² Climatology of the Isthmus of Panama, by Gen. Henry L. Abbott, published 1899.

Climatological data furnished by the Weather Bureau.

ANCON, CANAL ZONE.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Mean temperature:												
1906.....		82	81	83	82	80	80	80	81	80	79	80
1907.....	80		80	81	81	80	80	81	81	79	80	81
1908.....	81	82	83	83	80	80	80	80	80	79	79	80
1909.....	79	80	81	81	79	79	79	79	79	79	77	78
1910.....	1 79	1 80										
Maximum temperature:												
1906.....		95	95	96	93	91	92	94	92	92	92	92
1907.....	92		94	95	96	95	95	93	93	91	93	92
1908.....	93	95	96	95	93	93	93	93	91	92	90	91
1909.....	90	92	93	95	90	89	91	90	93	91	90	90
1910.....	1 90	1 92										
Minimum temperature:												
1906.....		69	67	70	73	72	71	71	73	68	67	69
1907.....	66		66	64	70	70	71	72	72	70	71	70
1908.....	69	69	69	71	71	70	69	69	70	69	70	68
1909.....	68	70	70	71	70	70	68	70	70	70	68	66
1910.....	63	67										
Number of clear days:												
1906.....		4	3	0	0	0	0	0	0	1	0	1
1907.....	8		3	1	0	0	1	1	0	0	6	9
1908.....	18	13	10	5	0	0	2	2	2	0	0	5
1909.....	1	8	2	0	0	0	1	0	1	0	0	2
1910.....	0	0										
Number of partly cloudy days:												
1906.....		17	25	15	14	7	4	9	4	11	7	3
1907.....	14		16	25	9	5	8	6	3	7	7	18
1908.....	13	6	16	18	15	2	14	14	14	15	7	13
1909.....	25	16	25	18	7	8	10	11	12	7	7	13
1910.....	27	23										
Number of cloudy days:												
1906.....		7	3	15	17	23	27	22	26	19	23	27
1907.....	9		12	4	22	25	22	24	27	24	17	4
1908.....	0	0	5	7	16	28	15	15	14	16	23	13
1909.....	5	4	4	12	24	22	20	20	17	24	23	16
1910.....	4	5										

¹ Mean for 3 years.

Climatological data furnished by the Weather Bureau—Continued.

CRISTOBAL, CANAL ZONE.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Mean temperature:												
1907.....								79	79	78	78	80
1908.....	80	80	80	80	79	79	78	79	79	79	77	78
1909.....	78	79	79	80	80	79	78	79	79	78	76	77
1910.....	78	78										
Maximum temperature:												
1907.....								86	89	85	85	85
1908.....	84	84	83	87	89	87	86	87	90	90	83	84
1909.....	83	84	84	86	90	92	86	88	90	85	85	82
1910.....	82	82										
Minimum temperature:												
1907.....								73	70	71	71	72
1908.....	72	72	74	74	71	72	70	72	72	70	71	69
1909.....	70	72	70	72	72	70	70	71	71	71	69	66
1910.....	70	71										
Number of clear days:												
1907.....								2	1	0	6	17
1908.....	8	14	15	7	4	3	2	4	2	3	1	6
1909.....	6	9	11	10	1	1	1	1	4	0	2	5
1910.....	9	7										
Number of partly cloudy days:												
1907.....								17	16	18	11	10
1908.....	23	15	14	21	10	14	14	17	13	17	14	17
1909.....	16	16	15	12	19	24	19	18	15	18	12	11
1910.....	16	18										
Number of cloudy days:												
1907.....								12	13	13	13	4
1908.....	0	0	2	2	17	13	15	10	15	11	15	8
1909.....	9	3	5	8	11	5	11	12	11	13	16	15
1910.....	6	3										

AGRICULTURE.

Agricultural operations in the Canal Zone are confined mainly to the meager efforts of the native and West Indian population and are restricted to patch farming. The production of the local staple products, principally tropical vegetables and fruits, rice, and corn, is little in excess of the actual food requirements of the operators. The greater number of these farms, although occupying the smoother slopes of the larger valleys and never distant more than 5 miles in a direct line from the canal, are isolated and inaccessible, owing to the broken topography and the absence of good highways. They are reached only by narrow, winding trails, at no time passable for vehicles and often well-nigh or quite impassable for horses. Few streams have been bridged outside the immediate vicinity of the canal, and such little effort has been made to keep open the trails that a rider is forced to dismount frequently in order to pass under the low overhanging growth or to lead his horse across streams with difficult banks. During the wet season travel on foot is nearly as rapid and often more comfortable over the trails of the steep hill country where the pathlike "caminos" climb and descend steep, rocky slopes, cross streams flowing through narrow, gorgelike valleys, and wind along the gentler, though frequently boggy, slopes. Natives make surprisingly rapid progress over these difficult trails

either afoot or horseback. Travel through the dense tropical growth is impossible except by way of recently cleared openings.

CULTURAL METHODS.

Vegetable gardening is carried on quite successfully at various points along the line of the canal by Chinese, who employ the most efficient cultural methods at present practiced to any considerable extent. The products of these gardens are sold in considerable quantity at the market places of all the important towns of the Canal Zone. Americans object to the unsanitary methods of fertilization and handling and seldom use Chinese-grown vegetables.

Cultural methods followed by the natives are most primitive. Plowing is never attempted; in fact, the only plowed field seen outside the commission experimental gardens was that of an American. The machete and a sharpened stick comprise the farm equipment of the native Canal Zone farmer. (Pl. I, fig. 1.) West Indians have in some places taken up small farms near the settlements along the Panama Canal and are growing about the same crops as are produced by the natives. Their methods are somewhat more systematic and intensive, and they generally have an additional implement or two, such as the spade and grubbing hoe.

In clearing land usually the entire growth is cut with the machete and allowed to dry in place. Some of the tough palms are often left standing, for the reason that considerable labor and very hard tools are required to fell them. The hardwoods are generally converted into charcoal, the common cooking fuel of the country, although sometimes the whole mass is burned when sufficiently dry. Occasionally corn is planted in the undisturbed tangle of matted brush and left to fight for its existence. Without any soil preparation whatever, further than that resulting from the digging of holes for the seed, crops are planted and thereafter allowed to care for themselves, except for occasional cutting down of weeds. In some instances crops are planted in rows, but oftener there is no semblance of regularity in their field distribution. Mixed farming, in the sense of growing together a number of different species of plants, is the most common type of agriculture. Frequently a dwelling, usually a palm-thatched shack (Pl. I, fig. 2, and Pl. II, fig. 1), will, at some distance, be completely hidden from view by a luxuriant tangle of tropical fruits, vegetables, and ornamentals, such as papayas, chayotes, bananas, yams, sugar cane, roselle, antigonon, etc. Corn, cassava ("yuca"), sugar cane, pigeon pea, bananas, and plantains are more commonly grown separately. Corn and cassava are sometimes grown together, and often cassava and yams are grown along with taniens and eddo. Corn is generally planted in hills of five to eight stalks each, a practice that unquestionably has considerable to do with the low percent-

age of stalks producing ears. In many fields less than 50 per cent of the stalks produce ears, and these are so small that average yields rarely go above 15 or 20 bushels per acre. Except when grown strictly for forage, much better results would likely come from planting not more than two or three stalks to the hill, not less than 3 to 4 feet apart. Much improvement would result if more attention were paid to careful selection of seed.

RELATION OF SOILS TO CROPS.

On account of the prevailing clayey nature of the Canal Zone soils, selection for different crops has not been given the attention that might be forced in a region of greater soil diversity. But even the slight textural variations that do exist have considerable influence upon the character and yield of crops. The friable clay loams are much better suited to vegetables than are the stiff, heavy clays, although the latter may be suited to the production of limes and oranges under certain conditions. The condition of the soil with respect to drainage, organic-matter content, and surface configuration as affecting protection from wind and surface drainage has had much to do with the encouragement of the prevailing tendency to plant bananas, plantains, taniers, rice, and "Para" grass upon bottom and lower-slope soils; and yams, cassava, chayotes, beans, papayas, mangos, and avocados upon the better drained, friable slopes. No effort has been made to secure through systematic trial comparative information upon the crop adaptations and best cultural methods of the various types of land as influenced by soil texture and structure, elevation, rainfall, etc. Observations made during the course of this reconnoissance upon crops growing under widely varying conditions, coupled with field and laboratory examinations of the various grades of soil, have led to a number of conclusions in regard to local requirements of plants and relative crop values, as well as of agricultural possibilities of the several types of soil encountered. The conclusions are set forth in subsequent chapters.

MANURIAL PRACTICE AND REQUIREMENT.

Practically no manures or fertilizers have been used in the Canal Zone, except in Chinese vegetable gardens and in a small way in the experimental gardens of the Canal Commission and by an occasional white employee. No instances of the use of commercial fertilizers are recorded, and it is therefore impossible with present available knowledge upon the subject to say whether such fertilizers can be used profitably or just what applications would be best suited for the various crops grown upon different soils. It might be noted here

that acid phosphate has been used upon Costa Rican soils very similar to the alluvial lands of the southern half of the Canal Zone, but at elevations of about 4,000 feet, with much benefit to citrus fruits, particularly oranges and pomelos. The universal luxuriant growth of plants is not indicative of any particular lack of nitrogen, and it is likely that any need for this element could be largely met by growing leguminous plants, such as cowpeas and velvet beans, both of which do well on nearly all the well-drained lands.

There is no lack of evidence that the heavy clay lands representing the most extensive types are very much in need of both organic matter and lime, primarily as correctives of the unfavorable compact and intractable structural conditions. In one instance an accidental application of lime was observed to have improved very markedly a stiff clay soil by increasing its friableness through flocculation of the soil particles. Where intensive farming is to be carried on, such as would be necessary in the production of vegetables and fruits like pineapples, burnt lime, either in the quick or air-slaked form, could be used profitably upon nearly all the soils of the Canal Zone, but particularly upon the heavy clay loam and clay types. A broadcast surface application of 1 to 2 tons per acre harrowed or raked in, where not mixed with the soil by rains, several weeks before planting and preferably just after a green cover crop has been turned under, would probably be sufficient for an initial treatment. Subsequent applications could be made as indicated by structural conditions of the soil, the object being to supply sufficient lime and organic matter, either barnyard manure or green manuring crops, to impart a degree of friability favoring easy cultivation and the conservation of moisture during the dry season. Water-logged soil such as that occurring in the swampy area between Corozal and Balboa if reclaimed would likely require 2 or 3 tons of lime per acre in order to be brought rapidly into proper condition for healthful plant growth. Limestone suitable for the manufacture of lime can be secured at various places in the northern portion of the Canal Zone. That on the relocated railroad near Frijoles appears well suited for burning.

CROP ROTATION.

No attention is given crop rotation as a means of maintaining good soil condition, although results secured in the experimental gardens under the intelligent direction of an experienced horticulturist¹ proved the advantage to be derived from certain crop successions. The growing together of crops maturing or attaining proper development for harvesting, at different times, as under the native plan of agriculture, amounts to a sort of accidental rotation, the merits or

¹ Schultz.

demerits of which it can safely be said are undetermined unless the usual practice of abandoning land after three or four years' cultivation be taken as indicative of too severe soil usage under such a system of cropping.

It was demonstrated in the commission gardens, by the increased yields of subsequent crops, that cowpeas and velvet beans materially improve the soil, and there is no question that these legumes particularly should be grown in rotation with other crops. It was also shown to be desirable to turn under vegetable matter, especially green cowpeas, in order to supply the soil with organic matter needed to loosen it up so as to admit of proper circulation of air and moisture.

PREPARATION AND CULTIVATION OF LAND.

The flat bottom lands and gentler slopes should be broken by plowing to a depth of 5 or 6 inches and thoroughly disked or harrowed where possible a short time in advance of planting. Extreme care should be taken in all cases to run furrows with the contours of slopes to guard against erosion. It would probably be better not to plow decided slopes that have not been broken formerly, unless there is a heavy vegetable covering to be incorporated with the soil to increase its absorptive capacity and its power of resisting erosion. A large proportion of the arable land is entirely too steep to be plowed. But this method of preparing land does not seem to be especially necessary for many root crops and fruit trees, such as cassava, yams, mangos, etc., which apparently find suitable environment wherever the soil has been prepared thoroughly by hand tools to a depth of 18 inches to 3 feet over areas varying, according to the nature of the plant, from a few square feet to 1 or 2 square yards.

For vegetable gardens the Chinese select the lower slopes and lowlands, where the soil is partly colluvial and generally slightly friable (Pl. II, fig. 2). The soil is raked or spaded into beds about 10 inches high and 2 or 3 feet wide across the top, with an interridge space of about 2 feet. During the wet season the beds are usually made high and the tops slightly convex, while in the dry season they are lower and more nearly flat. The high, convex bed is quite effective in giving rapid drainage in wet weather.

By frequent hoeings the soil is kept well mulched and the entire garden in clean condition, scrupulously free from weeds. Liberal applications of manures, principally night soil, are made. Irrigation is practiced in the dry season, the plants being sprinkled two or three times a day from buckets carried either in the hand or suspended from a stick supported by the shoulders. Experience has shown that plants are not likely to be injured by scalding, even where sprinkled in the hot sun, except where they have suffered for a considerable time from lack of moisture or have been set out only a short time.

A great variety of vegetables are grown in these Chinese gardens. Some of the more important are a spindling variety of onions, a small wrinkled tomato, pole and dwarf beans, peppers, lettuce, radishes, cucumbers, parsley, carrots, celery, eggplant, and "pe-tsai."

Nearly level cultivation was practiced in the commission vegetable gardens (Pl. III, fig. 1), where with irrigation very good results were had with a number of northern vegetables. The land was plowed to a depth of about 6 inches, harrowed, and fertilized with barnyard manure. Irrigation was practiced during the dry season, the water being distributed by hose attached to 1½-inch standpipes connected with underground pipes and placed at convenient intervals through the gardens.

NORTHERN VEGETABLES.

Of a large number of varieties of tomatoes tried, several gave good results on lands not affected by nematodes. Some plants made as high as 10 pounds of fruit. The Early Jewel, Livingston's Globe, Crimson Cushion, Stone, and Ponderosa seem especially adapted to the conditions. (Pl. IV, figs. 1 and 2.) When about 4 inches high, the plants should be set on land prepared for level cultivation. Best results seem to be had when the plants are staked, pruned to about 7 "hands" per stalk, and not allowed to reach a height greater than about 4 to 4½ feet. Tomatoes set out from about the 1st of December until about March 1 have been found to bear well throughout the dry season with irrigation.

Others of the more important Temperate Zone vegetables that have been more or less successfully grown are cucumbers, eggplants, lettuce, beans, cowpeas, radishes, and carrots. (Pl. V, figs. 1 and 2.) Cucumbers, cowpeas, peppers, pumpkins, and a considerable number of tropical vegetables do quite well in the rainy season; in fact, there is little reason to doubt that with knowledge gained through systematic experimentation a sufficient supply of vegetables will be produced to replace, in a large measure, the canned and cold-storage products at present consumed by white employees. It is true that many obstacles will be encountered in the establishment of an agriculture upon a modern businesslike basis; and much remains to be determined through experimentation, especially as to manurial treatment and as to the best varieties of native and foreign plants.

INSECT PESTS AND PLANT DISEASES.

Many of the agricultural and ornamental plants now grown are constantly subject to the ravages of insect pests. Defoliation of plants by leaf-cutting ants is a source of much injury, requiring unceasing vigilance. This is especially the case with a number of flowers, young fruit trees, and ornamentals. One successful method



FIG. 1.—VIEW OF PART OF THE EXPERIMENT GARDEN AT EMPIRE, CANAL ZONE.

[This garden was established by the Isthmian Canal Commission in 1907 and used for the cultivation of vegetables, fruits, and ornamental plants.]



FIG. 2.—VIEW ON THE PASTURE LANDS OF THE SAVANNAS NEAR PANAMA CITY.



FIG. 1.—YOUNG TOMATOES AT EMPIRE GARDEN, SHOWING METHOD OF HAND HOE CULTIVATION.

[Under management of H. F. Schultz, then horticulturist of the Canal Commission.]



FIG. 2.—TOMATOES BEGINNING TO FRUIT IN EMPIRE GARDEN ABOUT MIDDLE OF FEBRUARY, 1908.

[Under management of H. F. Schultz, then horticulturist of the Canal Commission.]

of combating this pest is to force sulphur fumes at intervals into the underground habitations, by means of a burner and bellows arrangement, until the ants are destroyed.

Various plant diseases, as well as insect pests, are at present doing considerable damage, but can probably be controlled by the use of fungicides and insecticides, especially in the form of sprays. Upon soils locally infested with nematodes a number of vegetables have suffered severely or actually died out. Eggplants, tomatoes, and some varieties of cowpeas are very sensitive to "wilt" on such affected areas. The most effective method of combating nematodes is undoubtedly through the cultivation of resistant strains. For example, the Iron and Brabham, and, to a slightly lesser degree, the Whippoorwill, are varieties of cowpeas that have succeeded where other varieties have failed.

STOCK RAISING AND DAIRYING.

There is plenty of room for extension and improvement of the stock-raising industry. Upon a large proportion of steep-hill land suited only for forestry and perhaps the production of certain fruits, such as pineapples, mangos, etc., good grazing can be secured through the establishment of Guinea grass pastures. A number of native grasses, such as those which flourish upon the savanna lands (Pl. III, fig. 2), afford good grazing, while Para and Bermuda grass, cowpeas, velvet beans, corn, the sorghum known as "Guinea corn," sugar cane, and peanuts do well upon the alluvial and lower-slope soils and constitute excellent forage crops. Another good stock food is cassava, a crop that gives large yields with a minimum of attention. It might be well to add here that fine cattle, particularly the large, strong oxen used as draft animals in portions of Costa Rica, are fed almost exclusively upon chopped stalks of plantain, banana, and sugar cane.

In the latter part of the dry season the grasses of the Canal Zone are generally so parched that very little sustenance can be secured from cleared pastures. But stored forage and crops like cassava, sugar cane, sorghum, banana stalks, etc., could be depended upon to carry stock through the dry months to the rainy season—the season of green grass and other tender vegetation. With such possibilities for the local production of forage crops there is no necessity for the present relatively large importation at high prices of grain, hay, and other feeds by the few who are operating stock and dairy farms. At the time of this survey (November–December, 1909) the price of shelled native corn was \$2 gold per 80-pound sack, while bran was bringing \$2.50 per 100 pounds. It is not at all surprising under such conditions that the demand for milk is so much greater

than the supply and that the prices are exceptionally high. Milk from dairy farms of the savanna section is sold in the city of Panama at 25 cents gold per bottle containing one-fifth of a gallon. During the dry season the price is sometimes higher than this.

Pastured cattle are frequently so troubled with ticks as to require weekly applications of insecticides, and it is a common practice in the savanna section to burn over the pastures in the dry season in order to destroy insects troublesome to stock. The high death rate of young calves has caused much discouragement among cattle raisers. Notwithstanding these drawbacks the opportunities for establishing paying dairy herds appear good.

Very few hogs and goats are raised in the Canal Zone. A considerable number of hogs and goats are imported from points along the Pacific coast, the hogs principally from the Province of Chiriqui, in the high northern portion of the Republic of Panama. Some poultry is raised by natives and canal employees. In view of the ruling high prices there is unquestionably a good opening for raising both pork and poultry. Away from the noisy activities of canal construction the depredations of wild animals such as the tiger cat and jaguar would likely entail some loss to these industries.

RELATION OF TOPOGRAPHY AND HIGHWAYS TO AGRICULTURAL DEVELOPMENT.

With its range of topography, farming upon an extensive scale is impracticable in the Canal Zone under the existing conditions of miserable roads and unreliable and high-priced farm labor. Excellent coconuts can be grown, but their production upon a profitable basis is restricted to the limited areas of the low coast fringes. The best quality and yields of bananas and sugar cane can be secured only from the widely scattered and comparatively small areas of bottom and lower-slope colluvial lands. Cacao and rubber can be grown successfully over extensive and more or less continuous areas in some of the larger valleys, but the profit from such industries would be problematical, owing especially to inadequate transportation and labor. In some instances the difficulties of transporting produce over trails impassable to wheel conveyance and tedious to horses would turn the scale from profit to loss.

The only good roads in the Canal Zone are the sections that have been constructed by the Isthmian Canal Commission connecting most of the American settlements along the line of the canal (Pl. VI, fig. 1), extending several miles out from the city of Panama and the one leading from Empire to Las Cascadas plantation. Widespread agricultural development, therefore, can not be hoped for without general improvement of highways. The creation of Gatun Lake, with its far-reaching ramifications, will greatly increase transportation facilities by boat throughout much of the northern portion

of the Canal Zone and the country of the interior adjacent to the large streams, as the Chagres, Gatun, and Trinidad Rivers. High wages are likely to prevail until the canal is completed.

OPPORTUNITIES FOR PROFITABLE CULTURE OF VEGETABLES, FRUITS, AND ORNAMENTALS.

Small farming, including the production of vegetables and choice tropical fruits, such as the avocado, mango, papaya, pineapple, orange, guava, anona, etc., can be carried on profitably with the application of intensive methods, coupled with proper care in the selection of crop varieties and soil. The supply of pineapples, avocados, and papayas is very much below the demand, notwithstanding the fact that these fruits are apparently well adapted to a considerable portion of the zone. With the introduction of varieties of mangos better than the seedling types now grown this fruit could be made very much more popular with the northern population. As an evidence of the good opportunities for the production of choice fruits not only to supply local demand, but for export trade, the island of Taboga in Panama Bay may be cited. Here upon very steep slopes, including much extremely stony land, large quantities of delightfully flavored pineapples are grown for shipment. The mango and avocado (aguacate) are also shipped from this small island with profit.

There are good opportunities for establishing profitable ornamental-plant nurseries. The hardier varieties of the many beautiful foliage plants that thrive in this region could hardly fail to find ready markets in Temperate-Zone countries.

SIZE OF NATIVE FARMS AND CHARACTER OF DWELLINGS.

The average farm of the native or West Indian as operated in the Canal Zone includes from one-half acre to 2 acres of cultivated land, located upon the lower gentler slopes and bottom lands, although often embracing quite steep slopes. In most cases the Panaman lives in a palm-thatched shack at or near his farm, frequently in the midst of a wonderfully luxuriant growth of mixed fruits, vegetables, and ornamentals. Those living at a considerable distance sometimes build small shacks near the fields for housing products like corn and rice. West Indians who have given up canal work for farming or who cultivate small patches during spare hours from canal work occupy shacks, usually roofed with scrap tin, situated in the midst of their fields, which are mostly very near the canal.

LEASING OF AGRICULTURAL LAND.

Lands for farming can be leased from the Isthmian Canal Commission for a period not exceeding 25 years and not exceeding 50 hectares (125 acres) in extent. The annual rental price is \$3 per

hectare. It would seem that the law governing the disposition of land for agricultural purposes could be made very much more attractive to those thinking of taking up tropical farming, particularly in allowing longer leases and larger allotments of land. Fifty hectares of land, unless carefully selected, is not likely to include more than a very small area of good agricultural soil, and such a holding is insufficient to admit of stock raising upon a basis of any importance. Much land at present is apparently occupied by squatters who have held their farms for many years. These have not been disturbed, except where their occupancy has interfered with canal construction.

MANUFACTURED PRODUCTS.

Manufacturing among the natives is limited to the making of brown sugar and rum, both of which are products of the sugar cane. Rum is manufactured in large quantities by one factory located near the line of the Panama Railroad.

Sugar is made in a small way on the farms of natives. The small cakes wrapped in calathea leaves are carried to market on horses. (Pl. VI, fig. 2.) A few cigars from locally grown dark, strong tobacco are made at home for individual use. Charcoal is made by burning wood stacked in conical heaps covered with earth. Rice is husked by pounding the grains in a wooden receptacle, and corn is ground with rock grinders manipulated by hand.

PRIMITIVE CHARACTER OF FARMING METHODS.

That methods are of the most primitive character as compared with those of important agricultural countries is due in a large measure to the enervating climate and the few wants of the people. The native is an independent person who is not always ready to work, even for the best of wages, because of the contentment he finds upon his small clearing in the midst of sufficient fruits and vegetables to meet the food requirements of his family, with a small surplus for providing the few additional wants. He toils but little and cares less, knowing the small chance for a possible shortage of food.

FORESTS.

A large proportion of the Canal Zone is in natural forest, including a great variety of trees, many of which are valuable for timber purposes. The trees are indiscriminately mixed, there being few places in which certain species occur to the exclusion of others. Some of the most common forest trees are 2 varieties of silk cotton (*Ceiba*), something like 15 species of palms, and, as locally known, the anona, bocare, algarroba, mamecillo, Santa Maria, hucar, acacia, almendro, roble (the native oak). There are a number of hardwood trees grow-

ing in the Canal Zone, but many of these have been practically exterminated; such, for instance, as the true mahogany and *lignum vitæ*.

The most valuable timber trees are the roble, Santa Maria, *mamecillo*, *hucar*, *nispero*, and *cocobolo*. *Algarroba* and *acacia* are valuable for their content of tannin. The roble and Santa Maria are used by the natives for the construction of their dugouts (*cayucas*). The other trees mentioned are mostly soft wooded and of little value.

The silk cotton is a very conspicuous tree in the landscape, as its spreading top reaches well above the surrounding forest. One variety of this tree is strongly buttressed, the buttresses often extending 10 to 12 feet from the main trunk, which is limbless to near the top.

SOILS.

Ten soil classifications or divisions were made, there being a range in soil material from the fine beach sand through alluvial and colluvial clay loams of stream bottoms and lower slopes to the more predominant plastic, heavy residual clays of the hills. Probably 80 per cent of available agricultural land consists of heavy clay which has been formed through the decomposition in place of volcanic, igneous, and sedimentary rocks. There is no very marked departure from the generally prevailing heavy clay characteristics of the upland soils proper, while even the alluvial lands are comparatively stiff and high in clay content. The accumulation on the lower slopes of material washed from higher lying clay lands and the deposition in stream bottoms of material carried in running water have given rise to a considerable total acreage of clay loam containing sufficient organic matter and coarse grains to constitute a very desirable agricultural soil.

The sandy lands, which occur exclusively as narrow coast fringes, consist principally of the coarser and more resistant particles of rock fragments representing reworked and assorted stream sediments and shore-line degradation products which have been thrown up by wave action. It is unfortunate that there is so little sand in the predominating upland soils, for the reason that with increased friability attendant on a higher content of the coarser soil particles the lands would be adapted to a much wider range of crops and far less difficult of cultivation. Two important and interesting facts to be considered in connection with the soils of the Canal Zone are the little surface accumulation of vegetable mold and the strong resistance offered to erosion. Even in the dense tropical jungles, through which it is practically impossible to travel without clearing a path as one progresses, the soil is often practically without any covering of vegetable mold, the stiff, heavy clay being covered only by a few

leaves and fibers or a thin layer of decaying vegetable matter. This rapid disappearance of plant remains is due in a large measure to the fact that the high humidity of the rainy seasons, followed by the winds of the warm dry season, favors rapid disintegration and oxidation of plant remains. Stream-bottom land and much of the lower-slope colluvial soil usually contain sufficient organic matter to impart more or less favorable structural conditions. The range in organic-matter content of the residual types in the samples analyzed was from 1.75 to 8.30 per cent, with few below 3 per cent. This high average is rather surprising in view of the very low average degree of friability.

There are a number of factors that combine to explain the remarkable resistance to erosion offered by the soils of the Canal Zone. The universal low content of sand and high content of clay, coupled with the fact that the soils are never loosened by freezing, are conditions favoring a soil compactness and imperviousness extremely resistant to the cutting or erosive action of running water. The lands are further assisted in holding place against wash by the dense vegetation and the almost total absence of cultivation other than the mere digging of holes in which to plant the crops of small native farms. Small streams even during heavy downpours are seldom muddied to a greater degree than a somewhat milky opaqueness, while the larger rivers clear up with remarkable rapidity following the heaviest freshets.

The extreme surface inequalities of the region are due in a large measure to the existence in past geologic times of very different conditions favoring a far more active erosion than at present. Continuous shallow, clean cultivation of plow-broken steep slopes without frequent replenishment of organic matter and terracing unquestionably would result in destructive erosion, but by confining the breaking of land with plows to the gentler slopes and bottoms and by judicious handling of the more steeply inclined areas there need be little fear of the land being ruined by erosion. There is evidence which would seem to indicate that it would not be advisable to break the land suddenly to a greater depth than 6 or 7 inches, for the reason that freshly turned up soil weathers out rather slowly. The depth of plowing should be increased very gradually, something like an inch or two at a time. An application of lime would likely prove of considerable benefit in bringing the freshly plowed land into proper condition for healthful plant development. In the park near the railroad station at Panama ornamental plants have made very slow progress upon soil from which a considerable portion of overlying material was removed just prior to the planting, which goes to show that the newly exposed subsoil offers an unsatisfactory abode for plant life.

The upland soils especially of the Canal Zone are too clayey for best results with vegetables; in fact, such lands under Temperate Zone conditions would be classed as being adapted rather to grass and grain. Strong stimulation given plants by the tropical climate possibly makes the soils of this region better adapted to vegetables than they would be under the influence of a more temperate climate.

All types of soil, with the exception of the coastal sands, harden and crack during continuous dry weather where exposed to the direct rays of the sun. Disturbed when wet enough to run together or to be very sticky the soil puddles and with subsequent dry weather assumes a hardened structure very unfavorable to plant growth. It is a difficult matter to restore good tilth in such soil, especially where the content of organic matter is low and where liberal applications of lime have not been previously made. It will therefore be necessary in all cultural operations to guard against disturbing the soil when in a sticky condition.

The following table shows the content of phosphoric acid, potash, and nitrogen in four representative Canal Zone soils:

Chemical analyses of representative soils.

Soil.	Location.	Phosphoric acid (P_2O_5).	Potash (K_2O).	Nitrogen (N).
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
No. 22148. Red clay (steep hill land).	1½ miles north of Pedro Miguel....	0.12	0.06	0.24
No. 22161. Red clay (northern half of Canal Zone).	Near the Gatun Dam.....	.35	.04	.32
No. 22157. Chocolate-brown clay loam (stream bottom land).	1½ miles northwest of Empire.....	.19	.10	.38
No. 22166. Dark-brown clay loam (lower slope land).	½ mile north of Pedro Miguel.....	.17	.06	.33

The several classes of land encountered in the Canal Zone are described in detail in the following pages, and their crop adaptation and requisite methods of cultivation are given, in so far as experience has pointed out such adaptations and requirements.

The map accompanying this report is simply a reconnoissance map and shows only the general distribution and extent of the various soils of the Canal Zone. The base map is not very accurate away from the line of the canal. It shows little or no topography and only the general location of some of the major streams. A detailed soil map would show a network of narrow bottom lands and numerous patches of soil, to indicate the location and extent of which would require considerable time and a very careful plane-table survey.

STREAM BOTTOM AND LOW LAND (SOUTHERN HALF OF CANAL ZONE).

Along many of the drainage ways of the central and Pacific portions of the Canal Zone there have been built up, through the deposition of materials carried in suspension by running water, narrow

strips of rich alluvial clay loam and silty clay loam, varying in width from a few feet up to something like one-fourth of a mile, according to the size of the stream, its fall, and the width of its valley. In many places streams flow through very narrow valleys with such rapidity as to preclude deposition of suspended matter, while the short lesser streams nearly all have a fall too great to favor the formation of extensive bottom lands. These bottom soils have been built up very slowly, owing to the average rapid fall of streams and to the small degree of regional erosion. Overflows are rare and of such brief duration that crops are not liable to any considerable injury from this source.

The true alluvial soil in the southern portion of the Canal Zone consists largely of a dark reddish-brown to nearly black, slightly friable clay loam to silty clay loam, underlain at a depth of 12 to 14 inches by a stiff, rather plastic, reddish-brown to yellow clay.

In the occasional low, gently undulating stretches not strictly stream bottoms, such as that at Corozal, and along some of the lower, gentler slopes, there is a considerable total acreage of soil quite similar to the true alluvial deposits described above, especially in character of surface material and in agricultural value. There is in the soil portion of such land a range from reddish-brown to nearly black slightly friable clay to clay loam, while the subsoil, which is encountered at depths ranging from 4 to 15 inches, varies from a brown or yellow moderately plastic clay to mottled red, yellow, and drab extremely stiff plastic clay, resembling the Susquehanna clay of the United States. The soil is made up largely of alluvial and colluvial material, while the subsoil consists either of material washed from higher situations or, as is most generally the case, that formed by place decomposition of volcanic, igneous, and sedimentary rocks. Patches of this low-lying land, varying in size from a few acres to something like 50 acres, are scattered here and there throughout the southern half of the Canal Zone. Some of the most conspicuous areas are those in the vicinity of Corozal, Pedro Miguel, Empire, Las Cruces, Matachin, and Gorgona.

This general class of land, although having for the most part good surface drainage, includes occasional swales and depressions needing drainage outlets. It is very well adapted to cultivation with the plow, and irrigation can be practiced easily on the flat stream bottoms, as well as on most of the other areas, while contour and basin irrigation is possible on the more rolling areas.

The organic-matter content is usually sufficiently high (samples analyzed 4.11 to 5.56 per cent organic matter) to impart a fair degree of friability; in fact, this is the best-structured soil of the Canal Zone, with the exception of the sandy coast land. It works up surprisingly well in dry weather, attaining an excellent tilth for plant develop-



FIG. 1.—SNAP BEANS (HODSON'S WAX) IN BEARING ABOUT MIDDLE OF FEBRUARY, 1908.

[In Empire Garden, under management of H. F. Schultz, then horticulturist of the Canal Commission.]



FIG. 2.—CUCUMBERS IN EMPIRE GARDEN ABOUT MIDDLE OF FEBRUARY, 1908.

[Under management of H. F. Schultz, then horticulturist of the Canal Commission.]



FIG. 1.—SECTION OF A HIGHWAY CONSTRUCTED BY THE ISTHMIAN CANAL COMMISSION TO OPEN UP THE RICH AGRICULTURAL LANDS NORTHEAST OF EMPIRE, CANAL ZONE.
[These lands are now generally settled by West Indian negroes.]



FIG. 2.—A PANAMANIAN FARMER ON HIS WAY TO MARKET WITH A LOAD OF UNREFINED SUGAR (PANELA).

ment. There is generally sufficient slope, or adequate drainage ways can be easily constructed, to insure good surface drainage, which fact, coupled with the excellent absorbent power of the soil where maintained in anything like good tilth, makes this a soil capable of regaining good structural condition very quickly after heavy down-pours. But even this soil, where exposed, is susceptible to baking and cracking during the dry season, and it is necessary to plow under vegetable matter occasionally in order to maintain a satisfactory structural condition. A cover crop, such as cowpeas or velvet beans, plowed under green, followed by an application of about 50 bushels of burned lime per acre, distributed broadcast over the surface, would probably give very beneficial results. Organic matter plowed under at any time when the soil is in moderately dry condition would help to improve the tilth, but an application of lime in the quantity mentioned would likely prove sufficient for a period of three or four years. Small annual applications of lime, however, could be made.

Owing to its evenness of surface and friable structure, this type has the widest range in crop adaptation and is the most generally used of the Canal Zone soils. Upon it sugar cane, corn, rice, Para grass, velvet beans, sorghum (nonsaccharine), and many vegetables and fruits give average results. Of the soils of the interior it is also best suited to bananas and plantains. Where well drained, yams, taniers, eddos, and cassava do well. Cowpeas, tomatoes, eggplant, cucumbers, pumpkins, squash, beans, okra, sweet potatoes, peanuts, onions, leeks, cauliflower, parsley, carrots, etc., can be grown with very good results upon areas properly drained and irrigated. The experimental vegetable and ornamental gardens at Empire and the vegetable garden at Pedro Miguel are on this type of soil.

Some promising products that have not been given thorough trial on this land are mangosteens, navel oranges, and pineapples. Excellent navel oranges are grown on quite similar alluvial soil at an elevation of about 4,000 feet near Cartago, in Costa Rica.

By cutting corn, sorghum, cowpeas, velvet beans, and Para grass during the early part of the dry season abundant supplies of forage can be secured to carry stock through the dry months, when unirrigated crops have mostly dried up.

Such a variety of ornamental plants thrive on the colluvial phase of this soil that there seems little doubt that many of these could be extensively and profitably grown for shipment to the United States and other northern countries. Some of the most strikingly thrifty and beautiful are several species of palms, *Acalypha* (fire plant), *Dracena* (dragon plant), *Hibiscus*, *Coleus*, *Phyllanthus*, *Alocasia*, *Croton*, *Caladium*, *Taberna montana*, orchids, cannas, *Ipomæa*, roses, *Passiflora*, *Antigona leptopus*, *Clitoria ternatea*, *Panax excelsum*, and *P. rotundifolium*.

In no case should plowing be attempted when the soil is the least inclined to be sticky, else puddling and excessive baking are likely to cause serious difficulty with subsequent cultivation. When in proper condition the land should be broken to a depth of 5 or 6 inches and then thoroughly disked or harrowed. Ridging will be necessary in the poorer drained areas during the rainy season in order to raise the plant beds above the influence of standing water, thereby insuring better moisture conditions.

Acid phosphate has been used on land of this character in Costa Rica for citrus fruit with excellent results, stimulating healthful and steady growth. It is believed that a moderate application, 300 to 500 pounds an acre, would benefit vegetables and fruits on the type to a considerable extent. Some potash may be needed, but nitrogen should be secured largely by growing leguminous annuals, such as cowpeas and velvet beans, in rotation with other crops. One of these should be plowed under green occasionally, supplying the needed organic matter.

The following table gives the results of a mechanical analysis of representative samples of this class of soil:

Mechanical analyses of alluvial land (southern half of Canal Zone).

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
22168.....	Soil.....	0.2	2.0	2.4	8.0	14.3	30.9	42.3
22157.....	Soil.....	.6	4.2	5.0	11.5	9.6	32.9	36.1
22158.....	Subsoil.....	.6	1.6	1.5	4.9	10.6	35.0	46.0

LOWER SLOPE LAND (SOUTHERN HALF OF CANAL ZONE).

Throughout the southern half of the Canal Zone, the region of greatest surface unevenness, there is a considerable area of very good agricultural land, occurring as an intermediate class lying between the excellent stream-bottom and low, gently undulating areas on the one side and the less desirable steep hillside land on the other. This classification comprises those lower slopes having a moderately rolling surface configuration favorable in the main to cultivation with the plow. A considerable number of areas occupying shelf-like situations or depressions, coves and gentle slopes, is topographically well situated for irrigation, but a good proportion would require terracing or the construction of basins to admit of a successful artificial application of water.

This land is derived largely through place weathering of igneous and volcanic rocks, including volcanic breccias, diabase, rhyolite, basalt, andesite, and trachyte. In places sedimentary rocks have entered into the composition of the soil. Weathering has taken place

quite uniformly to considerable depths, there being few places where the underlying rock comes within 3 feet of the surface. Colluvial material has accumulated in many places along the gentler and lower slopes, sometimes to a depth of a foot or more, the soil here being practically the same in physical characteristics and agricultural value as the colluvial phase of the lower-lying class. There has been more or less accumulation by wash from above over perhaps 50 per cent of these gentler rolling lower slopes, making the soil distinctly more friable than the unmodified plastic residual clays.

The soil usually consists of moderately friable to rather stiff, brown to bright red and chocolate-red clay, having a depth of from 6 to 14 inches, depending upon position and consequent quantity of accumulated colluvial material. The red color represents more nearly original residual clay unaltered by surface accumulation of washed material. The subsoil ranges from a yellowish-brown in the lower situations to red or mottled-red stiff plastic clay in higher areas.

Much of the type has a very fair organic-matter content, the top 2 or 3 inches sometimes consisting of a very black loam rich in this material. Structurally this class of land is on the average less friable than the lower lands, but by liming and rotations, including an occasional turning under of a heavy growth of green vegetation, preferably one of the legumes, such as cowpeas or velvet beans, good tilth can be secured. A broadcast surface application of about 50 bushels of burnt lime per acre immediately following the turning under of such green matter would likely prove decidedly beneficial in improving soil structure and in overcoming acidity and other possible unfavorable soil conditions. If not beaten into the soil by rain the lime should be harrowed in as soon as possible after its application, in order to become thoroughly incorporated with the soil some weeks before planting.

Surface drainage is very good; in fact, the flow-off is so rapid that considerable damage by washing would likely follow careless shallow plowing of the steeper slopes. Furrows should follow the slope contours and in places hillside ditching or terracing should be practiced as protection against erosion. There would be less danger from plowing if the land were broken only where there is a heavy covering of vegetation to be turned under, so as to loosen up the soil and make it capable of absorbing a larger quantity of water. With a deep, thoroughly prepared seed bed at planting time crops could afterwards be given very effective cultivation with hand tools.

In the southern half of the Canal Zone this is the most extensive type of soil topographically well suited to agriculture. It can not be handled as easily as the bottom lands of this region, nor is it as well suited to vegetables and crops like Para grass, corn, sugar cane, and bananas. A considerable variety of crops find such land very well

suited to their requirements. Cassava, yams, tanier, roselle, okra, papaya, mangos, chayotes, cucumbers, pumpkins, peppers, beans, cowpeas, velvet beans, corn, and tomatoes have been grown, though in a very limited way, with a fair degree of success. In those areas having a fairly deep colluvial or friable soil vegetables succeed about as well as upon the alluvio-colluvial land previously described. In some places cacao and rubber have made excellent growth on this soil type. Coffee is grown on this soil by many of the Panaman farmers, who nearly always produce their own supplies of this product. There are indications that pineapples, avocados, and mangos could be made profitable crops. A number of scattering orange trees indicate promising results to be had from this fruit where given proper attention.

The following table gives the results of mechanical analyses of the soil and subsoil of the lower slope land.

Mechanical analyses of lower slope land.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
22162.....	Soil.....	0.6	6.0	4.0	15.1	14.2	35.9	23.8
22163.....	Subsoil.....	.3	1.9	1.9	8.3	17.8	31.4	38.5

STEEP HILL LAND.

Something like 75 per cent of the southern half of the Canal Zone is too steep and hilly to admit of cultivation with the plow. Much of this rough country, however, can be utilized, through hand cultivation, for a number of crops, particularly fruits. Many slopes are so steep and rocky as to preclude profitable agriculture and should be used instead for forestry and pasturage. A good many of the lower hills have smooth, gentle slopes and nearly all, even the highest, have rounded tops well adapted to pasture.

The soil in the main is a stiff, heavy, chocolate-red to dark-red clay, with an unusually low content of sand and remarkable uniformity of texture and structure to an average depth of at least 3 feet. On some of the steeper slopes the depth to parent rock is not more than a foot or two, while over a considerable total area stones are very abundant from the surface downward. In a detailed soil survey such areas would have to be classified as Rough stony land, unsuited to other purposes than forestry. The soil of this type is entirely of residual origin, mainly from trap rock. There are very few areas where material washed from above has influenced the character of the surface soil.

Notwithstanding the dense tropical growth, there has been little accumulation of surface mold, and on account of the extremely

rapid run-off any attempt to incorporate vegetable matter with the soil by plowing under green crops would expose the steep slopes to severe erosion. Organic matter in the form of barnyard manure or even green vegetation could be mixed with the soil over limited areas by the use of hand tools. Although the stiff, compact nature of the soil suggests an extremely low organic-matter content, analyses have shown a range from 2.26 to 3.14 per cent.

Agricultural operations upon land classified under this head are restricted by the unfavorable topography largely to the production of fruits and stock raising. Guinea grass thrives and, although considerable labor is required in getting it started, when once established it holds well and is relished by stock, affording very fair pasturage well into the dry season, withstanding the heat better than other grasses.

The production of fruits, especially oranges, is a possible source of profitable utilization of a considerable proportion of the steep hill country, particularly the bright-red clay phase such as occurs between Pedro Miguel and Araján. Several well-fruited trees were seen at a number of points within the Canal Zone, but as with a number of other promising fruits little or no attempt has been made to develop orange growing as an industry. Here and there a few fruit trees have been set out about native shacks, but usually such little effort has been made to promote their growth and productiveness that they can not be considered as representative of the fruit possibilities of the region. Pineapples do well, even on the steep, rocky slopes (Pl. VII, fig. 1), and undoubtedly could be made quite an important and profitable crop, with careful treatment and proper soil selection. Cassava, yams, tanager, mangos, and avocados do very well on those areas having considerable soil depth.

The following table gives the results of a mechanical analysis of a representative sample of the better grade of this land:

Mechanical analysis of steep hill land.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
2214S.....	Soil.....	<i>Per cent.</i> 0.2	<i>Per cent.</i> 0.6	<i>Per cent.</i> 0.5	<i>Per cent.</i> 1.7	<i>Per cent.</i> 3.9	<i>Per cent.</i> 17.9	<i>Per cent.</i> 75.2

YELLOW CLAY (SOUTHERN HALF OF CANAL ZONE).

Scattered throughout the southern half of the Canal Zone are small areas of very plastic and adhesive yellow clay, overlain with from 2 to 8 inches of brownish to nearly black clay loam. Such soil occurs most frequently along the lower slopes near drainage ways. The most extensive single area is that between Pedro Miguel and

Paraiso, including the prominent hill just north of the former place. This type is derived from place weathering of eruptive rocks, including chiefly breccias, diabase, and rhyolite. Over the greater part of the type the soil has been influenced by material washed from high levels. Where such colluvial material has accumulated to a depth of several inches there is a very favorable organic-matter content (5.7 per cent in sample analyzed) and the soil is fairly friable and retentive of moisture. A good proportion of the type, however, has a rather stiff clay surface.

Rock fragments, bowlderlike stones, and even rock outcrops occur with sufficient frequency in places to make cultivation with the plow impossible. Such areas and the steeper slopes like that of the hill between Paraiso and Pedro Miguel would require hand cultivation.

The type is not a very important one, owing to its limited extent. Results have shown, nevertheless, that it is a very fair agricultural soil, especially the gentle-slope phase and those areas having a mantle of friable soil over the usual stiff plastic clay subsoil. Pineapples have done very well on a stony phase of the type along the lower slope of Ancon Hill. A promising field was also seen near Paraiso. This land is very well adapted to cassava, yams, and corn. A number of northern vegetables, such as tomatoes, cucumbers, eggplant, etc., could be grown successfully on the black, loamy colluvial phase. Mangos and avocados should thrive.

Soil almost identical with this type is used very successfully for the production of beans in the higher altitudes of Costa Rica. Ornaments made rather slow progress upon this soil about the administration building at Culebra, but here some of the surface soil had been removed before the plants were set. The incorporation of lime and barnyard manure would improve the soil not only for ornaments but for vegetables and other crops.

The texture of the soil is shown by the following results of mechanical analyses of the soil and subsoil:

Mechanical analyses of yellow clay (southern half of Canal Zone).

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
22146.....	Soil.....	0.6	2.0	1.7	3.0	14.4	56.0	22.5
22147.....	Subsoil.....	.3	.8	.9	4.3	15.7	37.1	40.9

SAVANNA LAND.

Northeast of the city of Panama, extending from the coast inland to a distance of over 2 miles, lies a considerable body of gently undulating treeless land known as the "Savannas" (Pl. III, fig. 2).

History relates that this unforested area was used for pasturage at the time of the raid of Morgan and his buccaneers upon old Panama, more than three centuries ago. The fact that it still affords fair grazing without noticeable deterioration, although it has never been fertilized, and some of it at least has been frequently burned over, is in a way an indication of the durability of the soils of the region.

The soil consists of a chocolate or dull-red stiff clay of quite uniform character from a few inches to several feet deep. In places on the steeper slopes the parent rock, consisting of a variety of volcanic rocks, including tuffs and breccias, comes very near the surface and even outcrops. Soil depth increases to many feet with descent of the gentle slopes near the small streams and in the bottoms of the slight swales and depressions. As elsewhere throughout the southern part of the Canal Zone, the lower slopes of this type are more loamy, darker in color, and higher in organic-matter content as a result of the accumulation of material washed from above and the better conditions of moisture.

This is the most extensive single area of gently rolling land in the Canal Zone. Notwithstanding the prevailing smooth surface configuration, here is seen the only evidence of recent erosion of any importance, and even this represents only a few comparatively small areas. The cause of these eroded patches is not very clear, though it seems plausible that the washing had its beginning in paths worn along the slopes by cattle. That pumiceous lava flows are exposed in these eroded areas offers some evidence that the character of the underlying rock may have played an important rôle in this work by hastening the wearing away of the soil through a freer penetration of water. This erosion appears to have been in progress for a long time; in fact, its present rate is so slow as to seem arrested. Only a small total area has been rendered unfit for cultivation or pasturage, and in places grass is even encroaching upon the eroded spots, indicating a means of reclamation. The problem, therefore, is not a serious one.

A considerable number of attractive summer homes have been built on the savannas by citizens of Panama. Very little of this land is for sale, although much of it is used for pasturage (Pl. III, fig. 2). It affords good grazing throughout the rainy season, but with the beginning of the dry weather the grass slackens in growth and is soon completely parched. Pastures are sometimes burned over at this season to destroy insects. There are a few patches of vegetables, corn, and Para grass on some of the lower lying, more loamy areas. The greater part of the type is very well adapted to cultivation.

In plowing this land the furrows should follow the contours, and where the slope is steep a heavy covering of vegetation should be

turned under to loosen up the soil, thereby making it more absorptive and consequently less susceptible to erosion. Leguminous crops should be grown extensively, not only as a source of forage but as a means of supplying needed organic matter and for the other benefits to the land accruing from the production of such crops. The organic-matter content (1.75 per cent) of pastured savanna land, as shown by analyses of samples, is lower than that of any of the other soils of the Canal Zone, with the exception of the sandy coast lands. This is undoubtedly the result of continued grazing and burning.

Many vegetables, including tomatoes, cowpeas, beans, eggplant, okra, yams, cassava, tanager, chayote, etc., do well, particularly on the more tractable lower slopes. Para and Guinea grass, corn, bananas, papaya, roselle, sugar cane, and a number of the other crops suited to the region can be grown quite well here.

One of the most attractive features of the savannas is the facility offered by the surface for irrigation, especially on the lower slopes and flat areas. There are a number of small streams capable of supplying water, and reservoirs could be resorted to for areas not located near perennial streams.

The following table gives the average results of mechanical analyses of two representative samples of this type:

Mechanical analyses of Savanna land.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
22150, 22151.....	Soil.....	0.4	2.8	2.7	8.6	15.4	26.2	44.1

RED CLAY (NORTHERN HALF OF CANAL ZONE).

The greater part of the uplands east of Mamei consists of residual products from the decay, in place, of sedimentary rocks, chiefly argillaceous sandstones, calcareous argillaceous sandstones, and sandstone conglomerates. Outcrops of trap rock occur here and there in the section between Bohio and Mamei, giving rise to comparatively small areas of soil very similar in physical characteristics to that derived from the sedimentary rocks. (It is possible that in that part of the northern section of the Canal Zone not examined a greater proportion of the soil is derived from igneous rocks.) To the east of Gatun Lake the soil, so far as examined, appeared to be entirely derived from sedimentary rocks, chiefly argillaceous sandstone and calcareous argillaceous sandstone.

The soil is a heavy red clay of remarkable uniformity to a depth of at least 3 feet. Weathering has taken place to a much greater depth, but in this survey examinations were made only to a depth



FIG. 1.—A PINEAPPLE PLANTATION (PINERIA) ON THE ISLAND OF TABOGA, ABOUT 10 MILES FROM PANAMA CITY.



FIG. 2.—PATCH CULTURE OF COCONUTS ALONG THE CHAGRES RIVER BELOW GATUN.



FIG. 1.—BEACH MARKET IN PANAMA CITY.

[Farm products such as yautias, sweet potatoes, papayas, plantains, limes, etc., brought in from coastal settlements for sale from the boats on the beach at low tide.]



FIG. 2.—PART OF A COCONUT GROVE, OPPOSITE THE VILLAGE OF CHAGRES, AT THE MOUTH OF THE CHAGRES RIVER.

of 3 feet. There is not as much change in the character of the material with the descent of the slopes as is the case with the soils in the southern part of the zone. Although extensively derived from calcareous material, the soil is so uniformly compact and close in structure that lime is needed as a means of flocculating the soil particles in order to bring about greater friability. A ton or more of burnt lime per acre following the turning under of a green crop would improve structural conditions to a considerable degree.

This soil in color, texture, and structure is so nearly like the average of that of the southern half of the Canal Zone, derived from igneous and volcanic rocks, that in the absence of any reliable data upon the relative agricultural value of the two it is impossible to state whether there is any marked difference in their crop values.

Topographically the soil here is better adapted to cultivation with the plow, the hills being lower and the slopes much gentler. But this advantage is in a degree counterbalanced by the greater rainfall of the northern portion of the zone. The type seems to be better suited to the culture of fruits than vegetables, many of which show a marked tendency to produce leaf growth at the expense of seed or fruit. Corn does very well, while crops like guinea grass, cassava, tanager, yam, and pumpkins give quite satisfactory results on the somewhat better drained upper slopes. Bananas do quite well in the lower moist lands where protection is afforded against the wind. An excellent vegetable "acelga" (*Xanthosoma hastifolium*), which tastes something like spinach, is grown very successfully on this type. This plant can also be grown upon the other clay soils of the Canal Zone.

The following table gives the results of a mechanical analysis of a representative sample of this type:

Mechanical analysis of red clay (northern half of Canal Zone).

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
22161.....	Soil.....	0.0	0.4	0.4	3.4	8.8	29.6	57.4

BOTTOM LAND (NORTHERN HALF OF CANAL ZONE).

In the depressions and along the streams of the northern half of the Canal Zone there are narrow strips of alluvial soil which have been derived from the adjacent slopes. The soil is not so bright red as the residual upland and contains more sand. It consists of a slightly friable to stiff chocolate-red clay loam to clay of uniform characteristics 3 feet or more in depth.

This type is quite similar in crop value and adaptation to the alluvial soil of the southern portion of the zone. Excellent results are had with bananas, sugar cane, sorghum, rice, and Para grass. A number of other crops, including onions, cowpeas, and lettuce, should do fairly well.

The following table gives the results of mechanical analysis of a representative sample of this type:

Mechanical analysis of bottom land (northern half of Canal Zone).

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
22149.....	Soil.....	0.0	0.3	0.2	3.7	18.5	30.3	47.0

SAN PABLO CLAY.

In the vicinity of San Pablo and Mamei, near the relocated Panama Railroad, there is a body of soil derived from an impure grayish to nearly pure white limestone. In the dense, impenetrable growth that covers this land considerable dark-colored organic matter has accumulated in the surface 3 or 4 inches, making it slightly loamy or nearly black. The subsoil is a yellow to slightly mottled yellow extremely plastic and adhesive clay. Applications of lime would improve the structure of the soil, especially where the plastic clay comes near the surface.

Some fairly good corn, yams, taniers, and sugar cane were seen in a field which had been fairly well cultivated. The intractable structure of the San Pablo clay makes it a rather undesirable type, except where there is a friable upper portion several inches in depth.

The limestone here could undoubtedly be successfully used for making burnt lime or ground limestone for agricultural purposes.

The following table gives the result of mechanical analyses of samples of the soil and subsoil:

Mechanical analyses of San Pablo clay.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
22170.....	Soil.....	0.3	1.5	3.5	8.9	7.0	32.2	46.9
22169, 22171.....	Subsoil.....	.4	1.5	1.2	5.6	8.8	32.7	49.7

CHAGRES SILT LOAM.

Along the Chagres River and some of its lower tributaries, chiefly the Trinidad and Gatun, there are wide strips of bottom land consist-

ing of a dark-brown silt loam. At a slight depth the soil usually becomes light brown or chocolate brown, with little textural or structural change for a depth of many feet. A variety of soil material derived from the drainage basins of a number of streams and borne in suspension until deposited by overflow waters enters into the composition of the type. Occasional strata of sandy material, the result of deposition in rapid currents, are encountered at variable depths. This transported soil is extremely fertile, but owing to its liability to frequent overflow and its wet, soggy condition both drainage and protection from inundation are essential to its most profitable utilization for agriculture, especially in the production of crops like corn and vegetables. The extensive swamp areas between Bohio and Gatun support a nearly impenetrable growth of vines, trees, shrubs, and grasses, and in places the soil is so soggy and miry as practically to constitute marsh. The type will be largely submerged by the closing of Gatun Dam. The very fertile strip along the Chagres below Gatun is already partly used by natives for coconuts, bananas, and other moisture-loving crops.

The soil is highly adapted to bananas and coconuts do fairly well. Protected from overflow and effectively ditched, corn, sugar cane, sorghum, Para grass, rice, and a number of vegetables could be grown very successfully.

The organic-matter content is sufficient to insure good tilth where the soil is plowed when in the proper condition with respect to moisture, particularly with an addition of 40 or 50 bushels of burnt lime per acre.

Along the Rio Grande from its mouth to near Corozal and lying between the Panama Railroad and the lower slopes of the Ancon and Sosa Hills are about 2 square miles of low, flat, alluvial land which is subject to overflow and which remains in a permanent soggy condition. Its agricultural possibilities are about the same as those of the Chagres silt loam below Gatun Dam (Pl. VII, fig. 2). The soil is a dark-colored, very fertile silt loam to clay loam which, with good protection from overflow, such as may be secured by the construction of open ditches and dikes, would produce fine crops of rice, sugar cane, and probably a variety of vegetables. Heavy applications of lime would likely be required to bring this land into favorable condition for healthful plant growth. At present it supports a dense growth of mangrove and other water-loving plants.

There is some land quite similar to the Chagres silt loam along the water front of Limon Bay in the vicinity of Colon, and a considerable area along the old French canal between Mount Hope and Gatun.

The following table gives the results of a mechanical analysis of a sample of this type:

Mechanical analysis of Chagres silt loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
22155.....	Soil.....	0.1	0.2	0.2	4.7	18.6	53.3	23.0

COASTAL SAND.

At various points along the Caribbean shore there are fringes of flat, fine sand lying only a few feet above sea level and representing the coarser and more resistant grains of stream sediments and the products of shore-line weathering which have been reworked, assorted, and deposited by wave and tidal action. The constituents represent the more resistant particles of igneous, volcanic, and sedimentary rocks. There are large quantities of magnetite (25 per cent in one sample) and ilmenite, a considerable content of augite, hornblende, and zircons, while feldspar and quartz are present in small quantities. The content of silt and clay are very low, but there is usually enough organic matter to impart a slight degree of loaminess. The water table stands within 2 feet of the surface in much of the type.

Abundantly supplied with moisture and favored by the full strength of sea breezes, the soil and situation are admirably adapted to the production of coconuts. It is decidedly the best coconut soil in the Canal Zone, and some excellent groves have been established upon it. The composition of the type is exactly that required by a great number of vegetables, but proximity to the ocean would likely militate to a certain degree against the production of truck crops, on account of exposure to salt spray. Back from the water front good vegetables could probably be grown, especially with liberal applications of barnyard manure.

There is a comparatively small area of this type in the Canal Zone and most of it occurs as disconnected fringes along the ocean front, ranging in width from a few yards to about one-half mile. There is a small body on the Pacific side of the Isthmus near Venado.

The following table gives the results of mechanical analyses of the soil and subsoil of this type:

Mechanical analyses of Coastal sand.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
22153.....	Soil.....	0.2	7.3	17.7	64.9	7.2	1.7	1.6
22154.....	Subsoil.....	.0	6.9	19.7	55.2	5.5	3.9	8.6



RELIEF MAP OF CANAL ZONE AS IT WILL APPEAR
WHEN CANAL IS COMPLETED.



FIG. 1.—TYPICAL HILL IN CANAL ZONE NEAR PEDRO MIGUEL.



FIG. 2.—MIXED PLANTINGS AS PRACTICED BY MANY CANAL ZONE FARMERS.
[Okra, yams, pigeon peas, bananas, plantains, and taros occupying the same land.]

IRRIGATION.

Notwithstanding the heavy rainfall and its equable distribution throughout the rainy season, covering practically nine months of the year, the bright, sunny weather of the dry months causes such rapid loss of soil moisture that many plants are checked in growth and not a few are parched outright where water is not artificially supplied. All northern and a number of native vegetables require irrigation, while many other plants, such as cassava, yams, sugar cane, etc., are markedly benefited by artificial watering during the dry season.

Abundant supplies of good water for irrigation purposes can be secured with comparative ease either from the many perennial streams or from reservoirs. Chemical analyses show Canal Zone water to be very pure and admirably suited for irrigation, the alkali content being too low to cause any possible injury to the tenderest of plants. This has been thoroughly demonstrated in the commission experimental gardens as well as in the Chinese vegetable patches.

In the southern portion of the Canal Zone certainly 75 per cent of the land can not be irrigated upon an economical basis, although small terraced patches for vegetables, fruits, and ornamentals can be irrigated from reservoirs, even on slopes of considerable steepness.

The sprinkling method of applying water, as employed in the commission and Chinese vegetable gardens, has proven very successful; but whether this is the most economical method of irrigating and one which could be applied in the case of more extensive operations is questionable.

The flooding system could be used on some of the flat stream bottoms for grass, corn, and sugar cane, but areas suited to this method are very limited. Upon soils subject to baking and cracking, as is the case with a large proportion of those in the Canal Zone, it is said that many crops are liable to injury where flooding is employed unless they stand sufficiently close to shade the ground.

By leveling down and filling in slight surface depressions much lower-slope land probably could be effectively irrigated by a system of furrows following the contours with just enough fall to allow water to run through to the next furrow without causing erosion. The expense of leveling, however, is unusually high, and there is another objection to the practice in that many plants do not thrive upon freshly exposed subsoil. Slopes can also be irrigated by the construction of banks or levees following the contours, and placed at such intervals as will allow the water to be held back from the upper side of one bank to the lower side of the next bank above. This method is frequently practiced in checks—that is, the banks are so arranged that the land is irrigated in a section usually more or less rectangular in shape—the water being permitted to flow into the

checks from distributing ditches leading from the canal along the upper side of the field.

Other and perhaps better methods of irrigation could be devised upon the ground to fit peculiarities of local topography, the crops, and individual preference.

Fruit culture as yet has received too little attention in the Canal Zone to warrant any very specific suggestion in regard to irrigation. It is believed, however, that experiments with the irrigation of fruit trees would give some very interesting and valuable results. The basin and check methods of applying water would probably prove the most effective in fruit growing.

Whatever the method used in applying water, it will invariably prove the better practice to stir the soils frequently, at least the surface 1 or 2 inches, in order to prevent the formation of hard surface crusts. This can be done effectively and cheaply with the disk harrow, cultivator, or hoe, the cultivation being done as soon as the surface soil has sufficiently dried.

PART II. THE OUTLOOK FOR AGRICULTURE IN THE CANAL ZONE.

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Pomologist, and Assistant Chief, Bureau of Plant Industry.

Though the Isthmus of Panama has been for four centuries the most important portage of the Western Hemisphere the lands through which successive routes of travel have passed across it show little agricultural development. Man's impress on the country, except in the immediate vicinity of the Panama Railroad (completed in 1851) and the canal route, which lies in close proximity thereto through most of its length, is chiefly apparent through the destruction of practically all the more valuable timber trees that made up the original forest.

In so far as the Canal Zone is concerned, the total present crop production barely supplies the simple needs of the scattered rural population. This is estimated not to exceed 10 per cent of the present population of the zone. Aside from a scanty supply of milk from dairies recently established near the terminal cities, Colon and Panama, the products of a few Chinese vegetable gardens near these cities and near some of the larger canal-construction towns, the food supply of approximately 90 per cent of the population is practically all imported. That of the American population is brought chiefly from the United States, though in part from West Indian, South American, and European ports. Canned fruits, vegetables, fish, meats, and butter are largely used, though these more perishable products are supplied in large quantities in the fresh state from the United States. This is accomplished by shipment in refrigeration from New York and New Orleans to Colon, at which point such articles as require it are placed in cold storage, where they are available for daily distribution by supply trains across the Isthmus as required. The sustenance of the cities of Colon and Panama, which, though within the Canal Zone, are not subject to the jurisdiction of the United States, comes largely from the outlying portions of the Republic of Panama, where certain phases of agriculture have reached higher development and are on a larger scale than in the zone. This is especially true of the capital city, Panama, with a population of about 40,000 people, the food supply of which, except that portion brought

over the Panama Railroad from Colon, is mostly received by boats. (Pl. VIII, fig. 1.) Much of this comes from points on the Pacific coast of the Republic, which embraces a sea frontage of about 770 miles. A considerable proportion of the supply of coconuts is produced in scattered plantations along the Caribbean beach on each side of Colon. (Pl. VIII, fig. 2.) A sufficient production of bananas to permit of some exportation formerly came from the alluvial bottom lands along the Chagres River near Bohio and Gamboa. These will be submerged upon the completion of Gatun Lake, and the canal construction operations have already materially reduced the area of land suitable for the commercial production of this crop, which at this time does not exceed the needs of the present population.

Aside from these lines of production, the only agricultural enterprises of sufficient size to be significant are a single sugar plantation near Gorgona, which will be submerged and destroyed by the canal, and two hill plantations near Empire, in which plantings of cacao, coffee, and rubber are the chief features.

CHARACTERISTIC FEATURES.

The distinctive features of the Canal Zone which are essential to any consideration of its agricultural possibilities and which will to a large extent determine the character of its agricultural development are:

- (1) The humid tropical climate.
- (2) The broken topography of the surface and the clayey nature of most of the soil.
- (3) Present crops and methods.
- (4) The present and prospective demand for fresh vegetables, fruits, milk, and poultry products.
- (5) Scarcity of live stock.
- (6) The character of the population.
- (7) The land titles and tenures.

CLIMATE.

With a mean annual temperature of about 80° F., and an average daily range of from 72° to 86° F. and an extreme range of from 68° to 97° F., the climatic conditions are characteristically humid tropical. The annual precipitation, ranging from 70.19 inches at Ancon on the Pacific or "dry" coast of the Isthmus to 91.85 inches at Gamboa, in the interior, and 128.12 inches at Cristobal, on the Caribbean shore, indicates the excessive humidity which further characterizes the climate. It is that of a region of low elevation lying close to the thermal equator, in practically the same latitude as Sierra Leone and Siam.



FIG. 1.—THE NATIVE LONG-HORN TYPE OF CATTLE.

[Generally raised in Chiriqui and Los Santos Provinces of Panama and shipped to Panama City on coastwise steamers. The prevailing type in the zone outside the city dairies.]



FIG. 2.—AN ORCHARD OF PAPAYAS (*CARICA PAPAYA*) IN THE EXPERIMENTAL GARDEN AT EMPIRE, CANAL ZONE.

[The fruits of these trees averaged in weight from 6 to 16 pounds each, and were supplied to the Panama Railroad commissaries, where they were in great demand by the American employees.]



FIG. 1.—PART OF ANCON HOSPITAL HERD MAINTAINED ON HAY AND GRAIN SHIPPED FROM THE UNITED STATES.



FIG. 2.—A TYPICAL NATIVE CORNFIELD, WITH PALMS.

Notwithstanding the heavy rainfall and high average humidity, most herbaceous crops, including the forage crops and vegetables commonly grown, suffer severely for lack of moisture if caught at a tender stage of growth during the "dry" season (January to March, inclusive). This is especially true of the Pacific slope of the Isthmus, on which the larger proportion of the uninundated lands of the Canal Zone will be after Gatun Lake is filled. Under such conditions, except where water can be made available for irrigation, notwithstanding the favorable temperature, annual crops require about as close adjustment to the seasons as in those portions of the United States bordering on the Gulf of Mexico. On account of the broken topography and the torrential rainfall of the rainy season irrigation will be difficult, except in a few favored localities.

TOPOGRAPHY AND SOIL.

Next to climate the broken and lumpy topography of the canal strip is its most conspicuous feature from the agricultural viewpoint (see relief map, Pl. IX). Outside of swampy and marshy areas near both coasts, only a very small proportion of land level and smooth enough to till with modern farm equipment will remain uninundated after the completion of Gatun Lake. In fact, it appears doubtful whether more than 20 per cent of the surface could be brought under the plow in fields or plots large enough to render horse or mule power practicable. The lands possibly suitable for the plow consist chiefly of narrow, broken strips of bottom land along the stream valleys and the adjacent lower slopes of the hills, which are generally steep and broken. As the streams, though carrying very little water at most times, become raging torrents for short periods at frequent intervals during the rainy season, the lands along them, which are the most fertile and valuable on the Isthmus, will require very careful handling to avoid destruction of both crops and soil when brought under cultivation. As will be observed from Mr. Bennett's notes and soil analyses, the prevailing soils available for agricultural use are nearly all red clays.

The steepness of the upper slopes (Pl. X, fig. 1) is such that at first glance deep and destructive erosion would appear inevitable upon the removal of the forest and jungle cover, but the tenacity of the soil is such and the rapidity with which the native vegetation covers the ground when it is denuded by man or by fire is so effective that little damaging erosion is observed. The most notable exceptions are in the trails or paths where constant use for long periods has resulted in the wearing of deep gashes into the red-clay hillsides. Such slopes as would almost anywhere in the southern United States be quickly destroyed by erosion under an annual rainfall less than half of that on the Isthmus show little damage from this cause where

they have apparently been farmed over in a desultory and migratory way for centuries. The most conspicuous exception to this general condition is the erosion noticeable on the savannas along the Pacific coast near Panama City. Here on gently rolling slopes the clay soils, apparently derived from rock of volcanic origin, in a region practically devoid of timber for many centuries and steadily grazed by cattle and horses since the early days of its occupation by European colonists, considerable areas have lost their plant cover and are badly gashed and galled by storm water. This is apparently due in part to a lower tenacity of the soil than elsewhere in the Zone, but primarily to overgrazing and trampling by cattle when wet.

The small proportion and scattered location of the plow lands will probably prevent their profitable utilization unless the hillsides above them can also be profitably utilized. The key to the agriculture is therefore the rational and profitable use of the hillsides.

PRESENT CROPS AND METHODS.

The native method of migratory farming, which is practically universal in the Canal Zone, has held erosion injury down to a minimum. While the clearing is frequently done with fire, so that the surface is burned clean and bare, the stumps of trees and the roots of herbaceous perennials are rarely killed or removed. Among these roots and stumps the crop, usually of corn, cassava, or yams, or two or more of these together (Pl. X, fig. 2), is planted without plowing, grubbing, or other general stirring of the soil. Both the crop and native vegetation quickly sprout under the tropical warmth and humidity, so that the growth and development of the crop are in close competition with the reawakened, long-established native vegetation.

Practically no cultivation of the soil is practiced, either before or after planting, the activity of the planter being limited to an occasional slashing down of the wild growth with the universally used machete. Such growth, thus cut, remains as a mulch for the growing crop and quickly decays, but is rapidly succeeded by new growth from the old roots and from seed from the surrounding uncleared lands. This general method appears to be universally practiced with field crops, like corn, cassava, and yams, and with such tree crops as cacao, coffee, and rubber, in so far as the culture of these has been attempted in the Zone. After a few years of cropping the field is abandoned and allowed to revert to its original condition, a new area being cleared to take its place.

Practically the only exceptions are a few small gardens near shack dwellings, where, in some cases, a few square rods have been grubbed free of wild plantain and other persistent vegetation to permit the planting of peppers, beans, chayotes, granadillas, roselle, and other

garden vegetables and fruits, less tolerant of crowding by other vegetation than the staple crops. Cultivated patches of sugar cane, located on rich bottom lands and low slopes where the gentleness of slope and the spreading root habit of the crop render erosion impossible even in the absence of a continuous soil cover, are occasionally found.

This migratory cropping, though resulting in quick exhaustion of the readily available fertility in the upper soil layers, has had the advantage of reducing soil erosion to the minimum compatible with the production of agricultural crops. It suggests the practicability of developing a method of soil handling by mixed cropping with congenial crop plants, which would render possible the continuous maintenance of fertility and productiveness under cultivation, of many of the readily accessible lands which otherwise appear incapable of permanently productive use with a reasonable expenditure of money and labor.

PRESENT AND PROSPECTIVE DEMAND FOR AGRICULTURAL PRODUCTS.

The present demand for agricultural products in the Canal Zone is peculiar and, to a considerable extent, abnormal in character. The large temporary population includes some 9,000 Americans and Europeans mostly unused to fresh tropical products. Palates accustomed to Irish potatoes, lettuce, cabbage, and garden peas do not readily adjust themselves to yams, taniers, chayotes, and similar tropical vegetables which satisfy the tropical appetite. The efficiency of the commissary service built up and maintained in connection with the canal construction, in its handling of perishable products in refrigeration, has made it possible for the northern population to secure their fruit and vegetable supply from northern markets in fairly sound condition and at a very reasonable cost, considering distance of transportation and risk of deterioration. The result is that the table fare of the "gold" employees is substantially of the same character as that to which they were accustomed in the north. The hotel menus in the Canal Zone at the time of this reconnoissance (November and December) were conspicuously devoid of tropical products, being substantially identical with those of the passenger steamers plying between New York, New Orleans, and Colon. The same condition existed in private families in the zone. Practically the only tropical vegetable observed in use was an occasional serving of yam (*Dioscorea*), which when properly cooked and served constitutes a fairly acceptable substitute for the Irish potato. Fruits of tropical production in common use were bananas, limes, pineapples, and papayas (Pl. XI, fig. 1). Of these

the bananas, limes, and papayas were of local production. The pineapple supply comes in part from Jamaica and in part from Taboga Island in Panama Bay, where a very considerable production of this fruit of high quality has been developed. The papaya, grown in a small way throughout the zone and brought in by trail and boat from elsewhere on the Isthmus, meets a strong and increasing demand among the northern population. During the dry season mangos and avocados are available in considerable quantities, though reported to be of rather indifferent quality.

Up to the present time the chief demand has been for a fresher supply of northern products than can be had through long-distance transportation. The local production of most such crops, except under very special conditions and at great labor cost, appears impracticable, because of lack of adaptability of most northern food plants to the prevailing tropical conditions. It appears likely that suitable forms and varieties of some of these could eventually be developed by systematic breeding, but there is little to encourage commercial effort along this line in the Canal Zone under existing labor conditions, which afford abundant opportunity for employment of all available able-bodied men at double or treble the wage rate for agricultural labor elsewhere in the American tropics.

Were present racial and economic conditions likely to continue in the Canal Zone, with a continuous importation of northern products in refrigeration for sale to the major portion of the population at cost, as is the case at the present time, there would appear to be little to encourage agricultural effort under the generally unfavorable existing conditions.

With the opening of the canal to commerce at an early date, however, it appears reasonable to assume that very different conditions will develop with regard to many products. The demand for fresh fruits, vegetables, milk, eggs, etc., to supply steamers carrying passengers may reasonably be expected to develop promptly. With regular and frequent steamer service to northern cities, the surplus of the better-known tropical fruits, such as the choice kinds of bananas, pineapples, mangos, avocados, and eventually papayas, cherimoyas and other anonas, sapodillas, and probably mangosteens and durions, could doubtless be disposed of under conditions that would render their culture profitable.

The outlook for northern demand for tropical vegetables appears rather less encouraging, though with proper attention to the development of choice varieties and the handling of the product in attractive form, such products as tomatoes, eggplant, dasheens, chayotes, and some of the better yams, would seem worthy of consideration.

LIVE STOCK.

The scarcity and inferior character of the live stock observed on farms in the zone is noticeable (Pl. XI, fig. 2). This is apparently due in large part to the lack of pasture and the almost total lack of attention to the production of forage crops. Horses and mules owned and used in connection with the canal construction work were generally in good vigor and thrift, though reported subject to frequent losses from certain tropical diseases not as yet understood by the veterinarians there. Horses are maintained largely on hay and grain imported from the United States, though some local corn is fed.

Very few horned cattle were observed outside of the dairies near the terminal cities, most of which have been established by Americans rather recently. At Ancon Hospital, however, fair success has been attained with a herd of milch cows imported from the Southern United States (Pl. XII). These are maintained largely on imported hay, bran, and cotton hulls, the feed derived from pasture constituting merely a supplement to the stable ration. While the general health of the adult cattle is reported good, much trouble with ticks is experienced and the mortality among calves is very heavy. Hogs are raised in small numbers. Domestic fowls, including turkeys and ducks, are commonly found on the shack farms.

CHARACTER OF POPULATION.

The climatic conditions will of necessity determine to a large extent the character of the agricultural labor. At present this is practically all Panamanian and West Indian, though some Spanish laborers were employed on the largest cacao, coffee, and rubber plantation in the zone in 1909. Experience elsewhere in the humid Tropics indicates the practical certainty that the heavier manual labor of the Canal Zone will need to be done by the races of tropical rather than those of Temperate Zone origin, even where the enterprises are owned and administered by the latter.

There are at the present time approximately 35,000 West Indians and others of tropical origin in the Canal Zone, mostly of the Negro race. They are hearty and easily satisfied consumers of tropical products. Most of the able-bodied men are employed with considerable regularity in the canal construction. A few of these grow much of their sustenance in small patches about their shacks, which fringe the white settlements along the line of the canal. The total product of these small mixed plantings, in which, unlike those of the native Panamanians, some cultivation with mattock and grub hoe is practiced, is considerable. Their tastes and needs are simple, and while at present a large proportion of their food supply is imported,

a considerable part of the population of this character could maintain itself on the products of the soil if either encouraged or permitted to remain when the completion of the canal ends the need for their labor on construction work. Under competent supervision these laborers might be expected to furnish a sufficient and reliable source of agricultural labor.

LAND TITLES AND TENURES.

The public lands, including those of the Panama Railroad, can not be sold, but such as are not needed for public use are available for lease for actual settlement and cultivation by the leaseholder. Such leases are limited by law to areas not exceeding 50 hectares (approximately 125 acres) and for periods not exceeding 25 years. The rental charge on such agricultural lands is \$3 per hectare, or \$1.21 per acre per annum.

On account of the broken topography, the proportion of land suitable for profitable agricultural use in any symmetrical tract is likely to be relatively small, so that the prevailing rental rate, though apparently low, is actually high in many cases, based as it is, in the main, on unimproved lands. The limitation of the area leasable to one holder to 50 hectares renders it difficult to locate more than a small acreage of land suitable for any special crop by a single individual and will operate against the most efficient and economical development along agricultural lines.

Titles to agricultural lands privately held are understood to be much involved and confused through incompleteness of public records and conflict of claims of ownership. It appears probable that legislative action will in many cases be required to cure defects of this character.

CONCLUSIONS.

Large farming operations are impracticable in the Canal Zone on account of the broken topography. Small farms, operated by the proprietors or under a central directive management, through which crop rotations and handling could be systematized and controlled, constitute the probable course of best agricultural development, especially where valuable perishable products destined for shipment outside the zone are concerned, such as choice mangos, avocados, pineapples, mangosteens, chayotes, and other tropical fruits and vegetables which are apparently well adapted to conditions in the zone.

The staple crops best adapted to the conditions appear to be corn, cassava (known as "yuca"), yams of several species, sugar cane, plantains, bananas, and upland rice, with a large number of other tropical and subtropical crops of lesser importance in the zone, including cocoa, coffee, and rubber.

The methods practiced are most primitive and transient, and little effort appears to have been devoted to selecting and developing desirable types, which alone can create an efficient and profitable agriculture. The total crop production of the zone at present is in consequence very small, and the products in general are of low quality and incapable of maintaining other than very primitive standards of living. The occurrence of occasional choice strains and individual trees and plants of superior excellence indicates that great improvement in productiveness and quality of most of the products could be promptly secured by well-directed, systematic plant-introduction and plant-improvement work.

The most promising line of attack upon the agricultural problem of the Canal Zone will apparently be to develop a permanent mixed tropical agriculture with a distinct horticultural trend, in which hand labor of tropical origin will be the main dependence for tillage. In this way the existing and prospective conditions would favor the production of high-priced products requiring regular and frequent transportation service, such as will doubtless be available promptly after the opening of the canal for use.

One important feature will be the early working out of a method of mixed cropping in which soil maintaining and improving leguminous intercrops can be continuously used to replace the wild and intractable native vegetation of the present shack-farm agriculture.

To quickly and effectively develop such a method will doubtless require some intelligently directed experimental work, as it involves careful study of the whole question of plant relationships and antagonisms, one of the most important and far-reaching problems in tropical agriculture, as well as the control of injurious insects and plant diseases. To meet the obvious needs the following lines of work are suggested:

- (1) A careful study of the existing cultivated types of crop plants of the Canal Zone and the adjacent territory of the Republic of Panama, with a view to locating and perpetuating the better strains of such staple crops as have already demonstrated their adaptability to the conditions.

- (2) Systematic introduction of promising types and varieties from other tropical countries, with a view to securing the best and most valuable varieties and strains that have been developed under similar conditions elsewhere. This feature is of special importance in the Canal Zone because of the backwardness of the agricultural industry at the present time.

- (3) The adjustment of some northern types of vegetables and other perishable crops to tropical conditions by selection and breeding. This will probably be a slow and tedious undertaking, but the fact that the maintenance of the canal will probably necessitate the continuous

presence of a considerable population of northern birth and tastes, which is not likely to be quickly or easily reconciled to tropical vegetable products, renders it well worth while to undertake it.

(4) The development of more economical, effective, and permanent methods of farming, including contouring, tillage, crop rotation, and other points essential to the conservation of soil and the maintenance of soil fertility. Special attention should be given to the introduction and establishment of crops needed for maintaining and encouraging of dairying and the poultry industry and to the establishment of these industries on a stable economic basis.

(5) The production of useful timber on lands not suitable or valuable for general agriculture, including such trees as the various species of eucalyptus, teak, etc.

RECOMMENDATIONS.

To accomplish the foregoing suggested points with economy and dispatch there will be required—

(1) Practically the entire time and attention of at least one well-trained and equipped man, with capable assistants, acquainted with tropical plants and experienced in general agriculture and horticulture. This man, whether under the direction of the Isthmian Canal Commission or the Department of Agriculture, should work in close touch with the department and maintain close contact with tropical-research work throughout the world.

(2) Suitable areas of land for experimental and propagating uses would need to be made permanently available for such work, as the moving of experimental plots and collections of plants at untimely periods is fatal to their usefulness. To provide for the different types of plants that are likely to be adapted to the different portions of the zone, suitable plots should be available at representative points, such as the vicinity of Ancon, Pedro Miguel, Empire, and Mount Hope.

(3) Outlying plots for special experiments would be needed from time to time, but much of the experimental work needed outside of the points mentioned above could doubtless be arranged for in cooperation with individual planters, whether American, West Indian, or Panaman, if the experiments could be kept in view by frequent inspection. The educational influence thus exerted would go far toward securing prompt adoption of improved plant forms and methods of culture.

(4) In view of the numerical preponderance of West Indians and natives in the zone and the probability that these elements will continue to exceed the northern population, thorough instruction in agriculture in the schools maintained for them would appear advis-

able. This can probably be best accomplished through the systematic development of school gardens, in which a beginning has already been made. Such work would, of course, need to be carefully planned and executed in cooperation with the zone superintendent of schools, but should have the advantage of close cooperation and advice of the agricultural expert in the zone. The rising generation would in this way be brought into touch with such advances as are made, and would gradually acquire the new point of view and intelligent interest in rational and progressive agricultural methods.

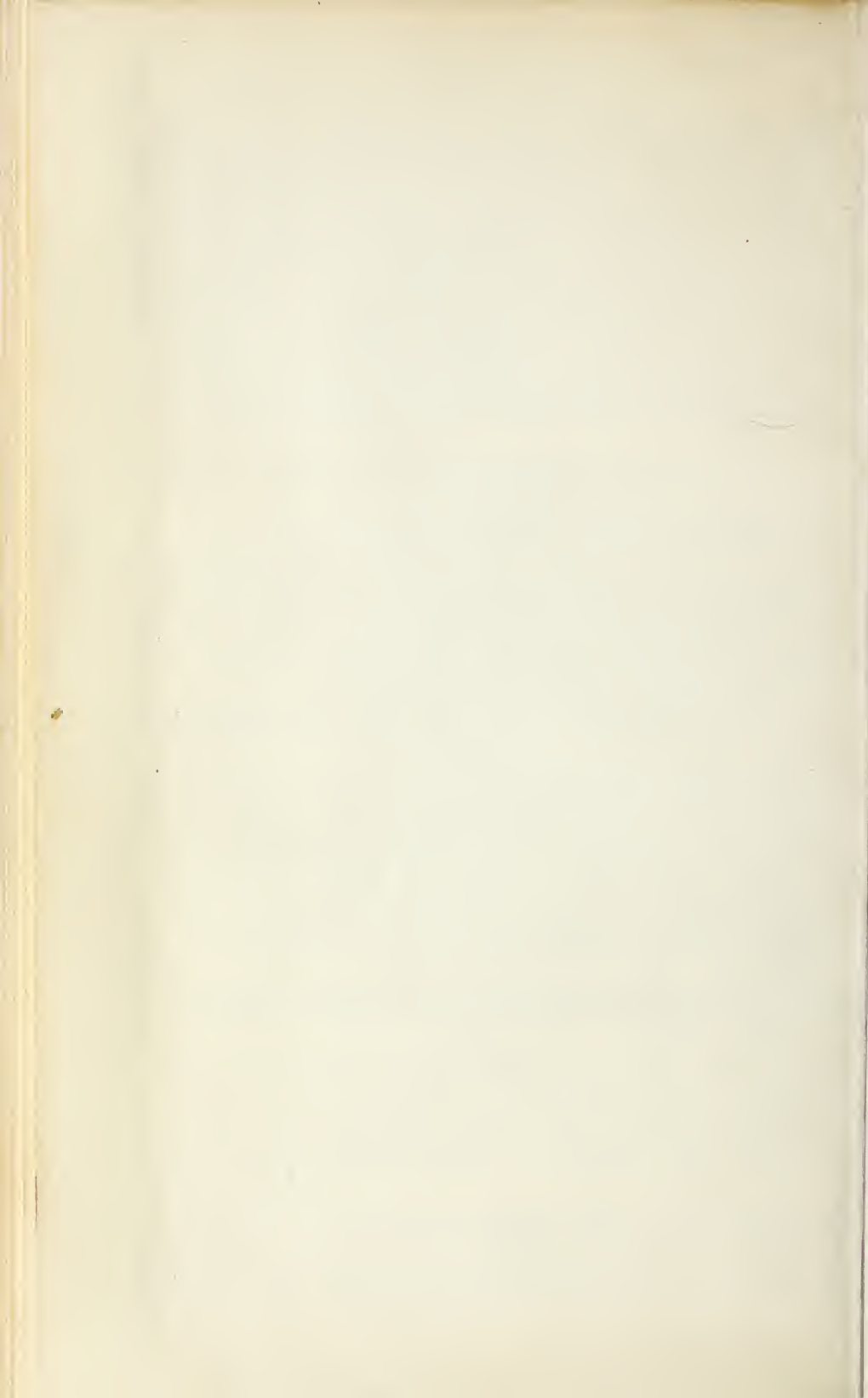
The land requirements of the work above indicated would be met if the following areas could be made permanently available for such work:

(1) At Empire, the present quartermaster's garden, consisting of about 12 acres. This to be used as a general experimental and propagating garden and central headquarters for such work.

(2) At Pedro Miguel, the present quartermaster's garden, consisting of 18 acres, of which about 12 acres is already cleared and available for use. Part of this (possibly one-half to two-thirds) will be submerged by the Pedro Miguel Lake, but until that time useful work with short-lived crops could be done and later the work there be readjusted to suit the changed conditions.

(3) Near Mount Hope, toward but below the Brazos Brook reservoir, a tract of from 5 to 20 acres for crops that endure excessive rainfall, such as bananas, plantains, etc.

(4) At Ancon, about one-half acre now occupied by the mango-steen plantation below the baseball park, toward the Balboa Railroad track. Close cooperative relations should be established with the management of the hospital grounds for adding to the collections there from time to time such valuable economic plants and trees as could be planted to advantage both for use and ornament. The collection of tropical trees and shrubs already established there is a nucleus about which an invaluable collection of economic tropical plants could easily be developed with very reasonable expenditure.



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